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THE REYNOLDS PUMPING ENGINE.

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By permission of the Hon. Mayor and Board of Aldermen of the City of Decatur, Ill., and of the contractors, E. P. Allis & Co., of Milwaukee, Wis., I am permitted to publish the following *résumé* of the results of a recent test trial of one of a pair of novel pumping engines recently erected for the water supply of that city.

The engines (two in number) are horizontal, of the single cylinder, condensing type, the steam and water ends in line, and the main shaft mounted in bearings on the top of air chamber, between the steam and water ends, a working lever or half beam turning on a center at the lower end and below the center line of engine, takes motion through a pair of short links connected with the steam end cross-head. Besides the pins on the beam to which the short links are connected, another pin, set back to describe an arc tangent to a center line from crank shaft to center of pin, takes the inner end of the main connecting rod, while the other end is attached to the crank. The crank is bent in the shaft midway between the two bearings, and to each of the overhung ends of the main shaft a heavy fly-wheel is keyed. Although the piston rod of the steam end and the piston rod of the water end are in line, each has its own cross-head, traveling on flat ways or guides in the engine framing, and connected together by horizontal struts; the space between the cross-heads and the struts being occupied by the upper end of the working lever and the short links which connect it with the steam end cross-head.

The pins receiving the links are overhung on each side of the working lever, and the pin receiving the inner end of the main connecting rod is supported in jaws central to the overhung pins, and over the center line of engine.

Owing to its novelty it is difficult, in the absence of a skeleton view or elevations of the engines, to make an easily comprehensible description of it. But it is sufficient for present purposes to have it understood as a horizontal direct-acting, single-cylinder, condensing pumping engine, with crank and fly-wheel mounted on the air chamber of pump, above the center line of engine, and connected with a pin on the working lever, which pin describes an arc tangent to a line drawn from the center of pin to center of crank shaft. The steam cylinders and heads are steam-jacketed, the condensation from the jackets being trapped into the hot well.

The pumps are of the double-acting piston variety.

The exhaust steam is led from the cylinder into a surface condenser with vertical tubes, around which the suction

is drawn from the well to the pump, the shell of the condenser being a part of the suction pipe. The circulation is, therefore, the water of supply on its way to the pump. From the lower end of the condenser the condensation is drawn off through a single-acting air pump, driven by an arm on the working lever shaft; a hot well in the line of the overflow pipe from the air pump receives the boiler feed water, from which a single-acting plunger pump, driven by an arm on the working lever shaft, forces it into the boilers.

The valve gear to the steam cylinders is of the well-known Corliss type, with Mr. Edwin Reynolds' improvements. The engines are finished with the Reynolds' style fly-ball governors, which regulate the cut-off and speed of engines automatically.

The speed at which the governors regulate ranges from fifteen to forty revolutions, according to the adjustment of a counterpoise spring which balances more or less the normal weight of governor balls. Each engine is complete within itself, and has no working connection with its duplicate.

The engines, with the exception of a slight difference in the diameters of the steam cylinders, are precisely alike in style and dimensions, and, by mutual agreement of the city and the contractors one engine was tested for duty under the terms of contract. For this purpose engine No. 2 was first selected for the trial, but upon discovering a leak in the steam trap connected with the jacket, engine No. 1 was tested instead.

The engines are of the following dimensions:

	Inches.
Diameter of steam cylinder No. 1.....	22.0625
Diameter of steam cylinder No. 2.....	22.1250
Diameter of pump cylinder No. 1.....	11.
Diameter of pump cylinder No. 2.....	11.
Diameter of steam piston rods.....	3.625
Diameter of water piston rods.....	3.1875
Stroke of steam and water pistons.....	36.

The engines take steam from two five-flue boilers, set with separate furnaces, and with steam and water connections common to both.

The terms of the contract, under which the engines were furnished, guarantee a duty of eighty million foot-pounds of work per hundred pounds of coal, upon an evaporation of ten pounds of water (to steam) per pound of coal. The economy depended, therefore, not upon the weight of coal burned under the boilers, but upon the weight of steam delivered to the engines, and as there could be no material variation of the quantity of steam consumed from hour to hour, under constant conditions of steam pressure, water load and speed, it was decided to limit the trial to sixteen hours' duration, during which time the steam and water gauges, vacuum gauge, water levels in boilers, temperature of feed water, and revolution counter were read at intervals of fifteen minutes. The temperature of the circulating water to and from the condenser was read hourly. Indicator diagrams were taken at regular intervals of fifteen minutes from 9.00 A. M. to 6.30 P. M., and afterwards at random to the termination of trial.

During the trial the connection between the hot well and the boiler feed pipe was closed, and the discharge of the air pump wasted through the overflow pipe. The feed water for the boilers was drawn from the force pipe and weighed in uniform charges of four hundred pounds, in a tight cask mounted upon an accurately adjusted Fairbanks platform scale. The suction of the boiler feed pump was provided with a vertical supply pipe, with a deep tin funnel at its upper end, into which the water from the weighing cask was discharged.

The rate at which the water flowed from the weighing cask into the suction pipe of the feed pump was the rate at which the water was supplied to the boilers, and with a uniform level of water in the boilers was the rate at which steam was consumed by the engine. The glass water gauges in the boilers were fitted with sticks graduated to quarter inches, and these were read and reported regularly every fifteen minutes, and frequently between the regular observations to govern the rate of delivery of feed water from the weighing cask.

In view of the fact that the contractor assumed no responsibility for the boilers, and based his guarantee of duty upon a hypothetical consumption of coal, it was held that he was entitled to saturated steam, and that from the water weighed to the boilers should be deducted the water of entrainment, if any was carried over in the steam.

The setting of the boilers was such as to prohibit superheating of the steam, and a material entrainment was, with reason, suspected before going into the trial.

The main steam pipe was tapped near the engine for calorimeter purposes, and samples of steam were drawn for tests of quality at least twice during each hour of the trial.

The great uniformity of steam pressure, load and speed, and of the rate of firing and water levels in the boilers, rendered more frequent tests of the condition of the steam unnecessary.

The scale upon which the condensing water and water of condensation were weighed, was graduated to quarter pounds, and would weigh to eighths.

The cask of wood was tight, and the thermometer used was a signal service instrument of James Green's manufacture.

The steam gauge and water gauge at the engine were read as found, and were compared with a new test gauge subsequent to the trial with the corrections noted.

The engines pump from a well connected with the Sangamon River by 105 feet of 24-inch pipe, and 190 feet of 22-inch pipe. At the junction of the 22-inch and 24-inch pipes a filter is interposed, which, however, is not effective, owing to the manner of connecting the filter with the river.

Previous to the trial, levels were taken of the surface of water in the Sangamon, of the upper edge of a spike driven in the side of pump well about one foot above the surface of the water, of the engine-room floor, of the center of pump cylinder, and of the center of water-pressure gauge from which to estimate the rate of inflow to the pump well through the inlet pipes, the suction lift as measured from the center of the pump cylinder to the surface of water in the well, and the head represented by the elevation of the water pressure gauge above the center of pump cylinder.

The distance from the upper edge of spike in the side of pump well to the surface of the water was measured once every three hours of trial; similarly the variation of the level of water in the river was noted.

Although under the terms of the contract the actual consumption of coal was not a factor in estimating the duty, the coal was weighed to the boilers for the purpose of determining the evaporation during the trial, and of stating to the city the actual performance of the boilers.

As the engines are usually operated, the condensation from the cylinder jackets and heads is trapped to the hot well and pumped back into the boiler; but, for the purpose of estimating the consumption of steam in the jackets the condensation was caught in a gauged vessel, its temperature and rate of delivery noted, and the jacket water wasted during the trial.

The trial for duty began at 8.00 A. M., Nov. 19th, and terminated at midnight, same date, with the following results:

Engine counter at 8.00 A. M.	261,420
Engine counter at 12.00 P. M.	298,800
Revolutions in 16 hours	37,380

The piston travel for the pump per revolution of engine is six feet, by scale measurement, and the total piston travel for trial was

$$37{,}380 \times 6 = 224{,}280 \text{ feet.}$$

The area of the circular side of pump piston is 95.033 sq. inches; of the pump rod, 7.9798 sq. inches, and of the annular side of pump piston, 87.0532 sq. inches; and mean area of piston, from which the duty is estimated, 91.0431 sq. inches.

The contractor "expressly guarantees a duty of eighty million foot-pounds per one hundred pounds of coal consumed, based upon an evaporation of ten pounds of water per pound of coal consumed, the duty test to be made with a water pressure of eighty-five pounds, the engines (two) pumping three million gallons in twenty-four hours."

The contract provides that each engine shall "have a steam cylinder twenty inches diameter by thirty-six inches stroke."

The actual diameter of steam cylinders agreed upon by the city and the contractor, subsequent to the contract, was twenty-two inches, which diameter was exceeded slightly, as shown in the dimensions given of steam and water ends.

Assuming the diameter of steam cylinder at 22.0625 inches, and the water

pressure gauge as substantially correct, then the relative pressure by gauge to be pumped against during the duty trial under the terms of contract was,

$$\frac{85\times382.879}{314.16}=103.59 \text{ pounds.}$$

An average of sixty-five readings, at regular intervals, of the water pressure gauge was 102.148 pounds. But upon test of the gauge subsequent to the trial it was found to be in error between the pressures at which it was worked—3.25 pounds—making true pressure by gauge 105.398 pounds.

The vertical distance from the upper edge of spike in the side of well to the engine-room floor was 13.58 feet; from floor of pump house to center of pump cylinder, 2.78 feet; and from center of pump cylinder to center of water pressure gauge, 4.97 feet. From which the head pumped against, including suction lift, was,

Average vertical distance from upper edge of spike to water in well during duty trial	1.41356 feet 0.6125 pounds
Vertical distance from upper edge of nail in wall to center of pump cylinder	16.36 feet 7.088 pounds
Suction lift, not including frictional resistances	17.77356 feet 7.7005 pounds
Vertical distance from center of pump cylinder to center of water pressure gauge	4.97 feet 2.1534 pounds
Average pressure by water pressure gauge	102.148
Error of gauge	3.25
True water pressure by gauge	105.398 pounds 243.258 feet
Total observed head, including suction lift	266.001 feet 115.252 pounds
Add for extra frictional resistance of water passages into and out of pump	1.000 pound 2.308 feet
When the total head becomes	116.252 pounds 268.309 feet

During the sixteen hours of duty trial there was weighed to the boilers 73 charges of 400 pounds each of water.

(In weighing the water to boilers the tare of the barrel was carefully taken each time a charge was delivered to the feed pump, the weights then advanced 400 pounds, and water drawn from the main until the scale balanced. Each charge of 400 pounds represented all the water above the outlet nipple in the cask.)

Of the total water weighed to boilers, part was lost by leaks over the grates in both boilers, part was drawn off for tests of quality of steam, and the remainder passed through the steam cylinder and jacket of the engine.

In reporting the trial to the City of Decatur, no attempt was made to account for and credit the boiler leaks and the whole quantity of water, less that drawn off for calorimeter purposes, was assumed to have passed through the engine.

From the calorimeter data a mean of nineteen tests gave as average:

Water heated .....pounds	200.
Steam condensed..... ..pounds	10.079
	Fahr.
Initial temperature by thermometer	54.84
Initial temperature by calculation..	54.844
Final temperature by thermometer..	107.76
Final temperature by calculation....	107.917
Apparent range of temperature.....	52.92
True range of temperature.....	53.073
Maximum range by thermometer with 10 pounds of steam	54.
Minimum range by thermometer with 10 pounds of steam.....	51.5
Thermal units per pound of steam..	1161.057
Temperature of steam at observed pressure, 64.18.....	1208.78
Difference	47.723
Latent heat at observed pressure....	894.95
Percentage of water entrained in the steam.....	5.3325

From which is obtained the following distribution of the water:

	Pounds.
Weighed to boiler.....	29,200.
Drawn off to calorimeter.....	202.35
Entrained in the steam.....	1,546.3
Delivered as steam to the engine....	27,451.35

The contractor guaranteed a duty of eighty million foot-pounds per hundred pounds of coal, upon an evaporation of ten pounds of steam per pound of coal; or for every thousand pounds of steam delivered to the engine there should be developed not less than eighty million foot-pounds of work. Under these conditions the duty by the conventional method was,

$$\frac{224{,}280\times91.0431\times116.252}{27.45135}=$$

86,471,762.42 foot-pounds.

The calculated displacement of the water piston is 28.377 gallons, and the weight

of water per gallon, 8.34 pounds, and the duty, based upon the discharge of pump, was,

$$\frac{37{,}380\times28.377\times8.34\times268.309}{27.45135}=$$

86,465,600.4 foot-pounds.

In the following table are given the average of observations during the trial:

Steam gauge at boilers .....pounds	65.648
Water level at beginning and end of trial, boiler No. 1.....inches	5.5
Water level at beginning and end of trial, boiler No. 2.....inches	6.25
Water level, boiler No. 1.....inches	5.154
Water level, boiler No. 2 .. ....inches	5.422
Steam gauge in engine room....pounds	64.18
Vacuum gauge.....inches	26.445
	Fahr.
Temperature of water to condenser ...	45.444
Temperature of water from condenser..	48.937
Temperature of water in hot well	87.531
Temperature of air in engine room....	59.288

From 9.00 A. M. to 6.30 P. M. the indicator diagrams were taken coincident with the readings of engine counter and water pressure gauge, regularly every fifteen minutes, the averages from which are given in the following table:

Initial pressure above atmosphere..lbs.	63.592
Terminal " " " "	0.152
Counter pressure absolute..... "	5.439
Effective vacuum.....inches	18.520
Mean effective pressure front.....lbs.	30.624
Mean effective pressure back..... "	29.163
Apparent cut off in decimal of stroke..	0.1176
Expansions by volumes, estimating clearance at 3 per cent.....	6.978
Expansions by pressure.....	5.461

The considerable percentage of water entrained in the steam, which was evaporated after cut-off by heat from the jacket, partially accounts for the discrepancy in the expansions by pressure and by volumes.

In order to compare the work of the steam end and the water end of the engine, I have estimated the duty for both ends, for the period of time during which the indicator diagrams were regularly taken. The duty of the steam end I have estimated as follows:

	Sq. In.
Area annular side steam piston.....	371.958
Area circular side steam piston....	382.958
Moment of load, front side of piston 371.958×30.624.....	11,390.842
Moment of load, back side of piston 382.279×29.163.....	11,148.402
Ft. lbs. of work per revolution of engine 3 × (11,390.842+11,148.402)=	67,617.732

During this interval of time the engine made 22,198 revolutions, and there was delivered to the boilers approximately 17,455.5 pounds of water, of which 136.975 pounds were diverted to the calorimeter; of the remainder, 923.597 pounds were entrained in the steam, and 16,394.928 pounds were delivered as net steam to the engine.

From which the approximate duty per 1,000 pounds of steam, of the steam end, was,

$$\frac{67{,}617.732\times22{,}198}{16.394928}=$$

91,551,388.02 foot-pounds.

During the same interval of time the head pumped against was:

	Pounds.
By gauge on force pipe.....	102.263
Error of gauge.....	3.250
Distance from center of water pressure gauge to surface of water in well.....	9.8539
Add for extra frictional resistance of water passages into and out of pump	1.0000
Total head.....	116.3669

From which the duty per 1,000 pounds of steam of the water end was,

$$\frac{91.0431\times116.3669\times22{,}198\times6}{16.394928}=$$

86,066,092.31

foot-pounds, and the efficiency of the engine, as represented by the work of the water end,

$$\frac{86{,}066{,}092.31}{91{,}551{,}388.02}=0.94008$$

leaving about six per cent. of the total power to overcome the frictional resistances of engine. The discharge of condensation from the jacket for sixteen and one-half hours was 1,014.75 pounds, at an average temperature of 189.3 Fahr. The corresponding discharge for the duration of trial is

$$\frac{1014.75\times16}{16.5}=984 \text{ pounds,}$$

representing an expenditure of

$$100\times\frac{984}{28{,}997.65}=3.3934 \text{ per cent.}$$

of the gross steam delivered to the engine.

The engines pump directly into the mains and no facilities offer for an actual

measurement of the discharge of pump. The pump was carefully measured for length of stroke and diameter of piston with dimensions previously given. From which the calculated displacement per revolution of engine is

$$\frac{91.043\times72}{231}=28.377 \text{ gallons,}$$

of which quantity I have estimated an actual delivery of 94 per cent., or 27.242 gallons per revolution. During the trial for duty the engine made 37,380 revolutions, representing a delivery of 1,018,305.96 gallons, equivalent to a delivery of 1,527,458.94 gallons in 24 hours.

The contract required two engines alike in style and dimensions, "each capable of pumping 1,500,000 gallons of water in twenty-four hours, against a pressure of one hundred and forty-five pounds per square inch" of pump piston. All the water lifted from the well by the pump came from the Sangamon River through 105 feet of 24-inch pipe and 190 feet of 22-inch pipe, to the well.

The rate of flow per minute during the duty trial, based upon the estimated discharge of pump, was

$$\frac{1{,}018{,}305.96}{16\times60}=1{,}060.74 \text{ gallons,}$$

the friction head for which, in a straight, cleaned pipe, free from obstruction, 24 inches diameter, and 105 feet long, is 0.014 foot, and the velocity head

$$\frac{1060.74}{60\times7.48}=2.363 \text{ cu. ft. disch. per}$$

second, and

$$\frac{452.39}{144}=3.1416 \text{ area sq. feet of}$$

24-inch pipe. Then,

$$\frac{\left(\frac{2.363}{3.1416}\right)^2}{64.4}=0.00878 \text{ head due velocity of}$$

flow, and total head for 105 feet of 24-inch pipe, discharging 17.679 gallons per second,

$$0.014+0.0078=0.02278 \text{ foot.}$$

The friction head for a flow of 17.679 galls. 2.363 cu. ft. per second through 190 feet of 22-inch pipe, is

$$0.0134\times\frac{24^5}{22^5}\times\frac{190}{100}=0.03935 \text{ foot,}$$

and the head due velocity of flow

$$\frac{380.13}{144}=2.63 \text{ sq. feet area 22-inch pipe.}$$

Then,

$$\frac{\left(\frac{2.363}{2.63}\right)^2}{64.4}=0.01252 \text{ foot, and total head,}$$

for 190 feet of 22-inch pipe, discharging 17.679 gallons per second, 0.05187 foot, and total head for both pipes, 0.07465 foot.

The actual condition of the pipe from the river to well is unknown; it may be heavily charged with silt or sand, it may be open at some of the joints, it may be incrustated, or it may be out of line. At all events, the actual head on the pipe at river and during the trial was 0.923 foot, which head, with a 22-inch pipe for entire distance, assuming the pipe to be straight and free from obstructions, represents a daily delivery to the well of over 7,000,000 gallons.

The estimate of an actual discharge of 94 per cent. of the calculated piston displacement is justified by the probable flow through the inlet pipe.

The contract provided that the engines shall be "made so as to be operated singly or together."

Subsequent to the duty trial of engine No. 1, both engines were operated for one hour, against a pressure by water gauge of 80 to 85 pounds, at an average speed of 26.85 revolutions per minute for engine No. 1, and 26.583 revolutions per minute for engine No. 2, the automatic cut-off gear controlling the speed of the engines.

The engines were also jointly operated for one-half hour, against a pressure of 142.15 pounds per square inch of water pistons, the maximum pressure attainable with the springs found on the "pop" relief valves attached to the force pipe.

The following table contains the general data and results of the duty trial:

Duration of trial .. ....hours	16.
Steam pressure in engine room.....pounds	64.18
Vacuum by gauge .....inches	26.445
Water pressure by gauge..lbs.	105.398
Total head (including suction lift) pumped against..pounds	116.252
Revolutions of engine per minute.....	38.9375
Piston speed of steam and water pistons.....feet	233.625
Duty in foot pounds per 1,000 pounds of steam.....	86,471,762.42
Percentage of useful effect developed by water end	94.008
Percentage of steam required to maintain the jacket.....	3.3934

The boilers from which steam was obtained for the engine during the duty trial were two in number, of the following dimensions:

Diameter of shells.....inches	48.
Length of shells .....feet	20.
Number of flues.....	5.
Diameter of flues.....inches	3-14 / 2-12
Heating surface shells (2).....	251.328
Heating surface flues (10).....	691.128
Heating surface heads (4).....	15.578
Heating surface, total..... sq. feet	958.034

The boilers were set with independent furnaces, of the following dimensions:

Length of grate bars.....	4ft. 2in.
Width of grate bars.....	4ft. 7in.
Area of both grates.....sq. ft.	38.03
Grate to boiler at front.....inches	20.
Grate to boiler at bridge wall .inches	25.

Chimney of brick, circular in section, 4ft. 6in. diameter, and 91ft. 6in. high from surface of grate at front.

Ratio heating to grate surface.....	25.191
Ratio grate surface to cross section of flues.....	3.986
Ratio grate surface to cross section of chimney.....	2.391

The water supplied to the boilers during the trial was 29,200 pounds, of which 1,557.09 pounds was entrained in the steam, and 27,642.91 pounds evaporated into saturated steam.

The coal burned during the trial was 6,000 pounds, representing an evaporation per pound of coal of

$$\frac{27{,}642.91}{6000} = 4.60715 \text{ pounds,}$$

from a temperature of feed of 48.937 Fahr.; corresponding to an evaporation from and at 212 Fahr. per pound of coal of 5.534 pounds.

The weight of ash and clinker weighed back at end of trial was 795 pounds, representing 13.25 per cent. of the total weight of fuel charged to the boilers.

The coal was of fair quality, and under good boilers, well set, would show an evaporation quite fifty per cent. above that developed during the trial.

The most important lesson to be learned from this trial of a pumping engine is the fact that a high duty can be had from a single-cylinder condensing engine. Of a list of duties before me the highest for this class of engine is 68,387,200 for single cylinder, beam crank and fly-wheel condensing engine, by Hubbard and Whittaker, for the Brooklyn Waterworks, reported 1860; and 65,824,581 for the same class of engine, by Mr. D. C. Cregier, for the North Side Pumping Works, Chicago, reported 1874. If the duty of single-cylinder condensing, crank and fly-wheel pumping engine can be raised to 85 or 90 millions, with the corresponding diminution in first cost over compound engines, it will certainly meet a want now felt, especially in works where the quantity of water pumped and revenue is small.

THE *Scientific American* says:—"The quality of movement of the particles of iron under pressure or percussion is a remarkable one, whether the change in arrangement is made while the iron is hot or when it is cold. Red-hot iron can be pressed to fill a mould as clearly and exactly as so much wax could be, and the grain of the iron will certainly follow all the contour of the mould. Thus the heads of pick-axes and articles of a similar form can be shaped by pressure, the metal that is removed to make the hole for the helve being forced to form the projection of the adze-like head. Cold iron can also be moulded into form by pressure—a method largely practised to finish drop forged iron articles. The heading machines for making rivets, bolts, and wood screw blanks shows some surprising results in the compression of iron; a No. 6 1 in. screw requires a piece of wire slightly more than 1½ in. long to form it. Yet the total length of the screw blank, headed, is just 1 in. Of this the countersunk shaped head is $\frac{1}{8}$ in. by $\frac{9}{16}$ in. widest, or top, diameter. Now, it has been proved by experiments with shorter bits of wire that less than $\frac{5}{16}$ in. of the extra $\frac{9}{16}$ in. is required to form the screw head. What becomes of the remaining more than $\frac{3}{16}$ in. in length of the original 1½ in. that makes the 1 in. screw blank? There can be but one answer—the iron is driven upon itself; in other words, $\frac{3}{16}$ in. of wire is compressed into $\frac{1}{8}$ in.—measuring under the head—so that 1 in. and $\frac{1}{16}$ in. of wire is compressed into $\frac{1}{8}$ in. in length without increasing the diameter of the wire." If this question is followed up, it will be found that the wire has increased in diameter, and that the specific gravity of the iron is but very slightly increased.

ON THE STRENGTH OF MATERIALS UNDER REPEATED STRESS.

By Prof. MANSFIELD MERRIMAN.

Written for Van Nostrand's Engineering Magazine.

It has been generally recognized for a long time that repeated varying stress is more dangerous than steady stress, and requires a higher factor of safety, or, in other words, that the allowable working unit-stress to be used in designing a bar should be less for repeated than for steady stress. The experiments of Wöhler and Spangenburg have also furnished the means of grading these working unit-stresses according to the range of strain, in a more satisfactory manner than mere judgment can do. These experiments were made by subjecting bars of iron and steel to repeated stresses ranging between certain limits. When the range was great it was found that the number of repetitions required to produce rupture was small, and that as the range was decreased the number increased. The unit-stress which would produce rupture after an enormous number of repetitions were thus determined for different ranges, the word enormous meaning several millions. The discussions of these valuable experiments have established the following laws:

1. Rupture may be caused by repeated applications of a unit-stress less than the ultimate strength of the material.

2. The greater the range of stress the less is the unit-stress required to produce rupture after an enormous number of repetitions.

3. When the unit-stress ranges from zero up to the elastic limit the number of repetitions required to produce rupture is enormous.

4. A range of stress from tension into compression, or *vice versa*, produces rupture sooner than the same range in stress of one kind only.

5. When the range of stress in tension is equal to that in compression, the unit-stress which produces rupture after an enormous number of repetitions is a little greater than one-half of the elastic limit.

In order to deduce a formula for the unit-stress s which will cause rupture after an enormous number of repetitions, let us consider a bar in which the stress ranges from p to a greater value P. These stresses p and P are the total stresses in the bar; if A be the area of its cross-section $\frac{p}{A}$ is the least, and $\frac{P}{A}$ is the greatest unit-stress upon it. The quantity s whose value is required should be the same as $\frac{P}{A}$. Let u be the ultimate strength and e the elastic limit of the material, which, like s, are given in pounds per square inch. Let f be that stress per square inch which causes rupture when p is equal to P, one being tension and the other compression.

According to the above laws the unit-stress s which will cause rupture after an enormous number of repetitions ranging from p to P is a function of the difference $P-p$, or of the ratio $\frac{p}{P}$. Thus

$$s=\Phi\left(\frac{p}{P}\right)$$

This function will be established by assuming an empirical expression with undetermined constants, and then finding the values of the constants from the experimental laws. Thus let

$$s=le+m\frac{p}{P}+n\left(\frac{p}{P}\right)^2,$$

in which l, m and n are constants to be determined. If p and P are both tension or both compression, the sign of the ratio $\frac{p}{P}$ is to be taken as positive, but if one is tension and the other compression, it is to be taken as negative. Now, if $p=P$, there is no range of stress, and the case corresponds to that of a steady load for which s is the ultimate strength u. Again if $p=0$, the case is that of the third law for which s is the elastic limit e. Lastly, if $p=-P$, the case is that of

the fifth law for which s has the value f. For these three cases the assumed function becomes

$$\text{For } p=\mathrm{P}, \qquad u=le+m+n,$$
$$\text{For } p=0, \qquad e=le,$$
$$\text{For } p=-\mathrm{P}, \qquad f=le-m+n,$$

From these three equations we find the three values

$$l=1 \qquad m=\frac{u-f}{2} \qquad n=\frac{u+f-2e}{2}$$

and the expression for s hence is

$$s=e+\frac{u+f}{2}\cdot\frac{p}{\mathrm{P}}+\frac{u+f-2e}{2}\cdot\left(\frac{p}{\mathrm{P}}\right)^2$$

This may be written in the form

$$(1)\quad s=e\left\{1+\frac{u-f}{2e}\cdot\frac{p}{\mathrm{P}}+\frac{u+f-2e}{2e}\left(\frac{p}{\mathrm{P}}\right)^2\right\}$$

which is often more convenient in discussion and computation.

This formula satisfies the three imposed conditions. If the ratio of p to P is one, the value of s is u as for quiescent stress. If the ratio is 0, the value of s is e as required by the third law. If the ratio is -1, the value of s is f as the fifth law demands. To ascertain its reliability for intermediate values of the ratio, a comparison with experiment is necessary.

For German Phœnix iron Wöhler found the ultimate strength u about 55,000 the elastic limit e about 31,000, and the vibration strength f about 16,500 pounds per square inch. For these values formula (1) becomes

$$s=31{,}000\left(1+0.62\,\frac{p}{\mathrm{P}}+0.15\frac{p^2}{\mathrm{P}^2}\right)$$

He also found that this iron when subjected to a tension ranging from 25,000 to 45,500 pounds per square inch did not rupture after four millions of repetitions. For this care the ratio of p to P is $\frac{25000}{45000}$ or $\frac{5}{9}$, and the formula gives $s=43{,}000$, which is a fair agreement with the observed value 45,500.

For Krupp's axle steel Wöhler found $u=105{,}000$, $e=50{,}000$, and $f=29{,}000$. For these values the formula is

$$s=50{,}000\left(1+0.76\,\frac{p}{\mathrm{P}}+0.34\frac{p^2}{\mathrm{P}^2}\right)$$

He also found that this steel when subjected to a tension ranging from 36,400 to 83,200 pounds per square inch did not rupture after twelve millions of repetitions. For this case the ratio is $\frac{7}{15}$, and the formula gives $s=70{,}000$, which is considerably lower than the observed value.

For soft spring steel Wöhler found $u=115{,}000$ and $e=52{,}000$. The value of f was not determined, but by analogy with the preceding it may be taken as 27,000 pounds per square inch. For these values formula (1) becomes

$$s=52{,}000\left(1+0.84\,\frac{p}{\mathrm{P}}+0.36\,\frac{p^2}{\mathrm{P}^2}\right)$$

In the following table the first and second columns give the values of p and P, both tensile unit stresses, for which bars did not rupture when the stress was repeated over thirty million times. The third column gives the ratio of p to P, and the fourth the value of s computed from the formula. As p and P are here unit-stresses the values in the second and fourth columns should be the same, and the fifth column contains their difference. The agreement between the observed and computed values, though not close, may be regarded as fairly satisfactory.

p.	P.	$\frac{p}{\mathrm{P}}$	s.	Diff.
68,640	104,000	0.66	89,000	−15,000
62,400	93,600	0.67	89,500	− 4,100
58,240	83,200	0 7	91,500	+ 8,300
51,600	83,200	0 5	78,500	− 4,700
31,200	72,800	0.36	69,000	− 3,800
26,000	72,800	0.43	74,000	+ 1,200

Unfortunately no experiments were made by which the formula may be tested for the values of the ratio between 0 and -1. Further experiments on repeated stresses are much needed to perfect our knowledge of the subject. Wöhler's researches give three definite values of s, namely the values u, e, and f, corresponding to the ratios 1, 0, and -1. If the ratios be taken as abscissas and the values of s as ordinates, three points are determined not in a straight line, and formula (1) is the simplest curve which can be [illegible]d through those three points and is [illegible] an approximation to the true law.

For wrought iron the value of f is about $\frac{1}{2}e$, and the value of u about $2e$, and the formula is

$$s = e\left(1 + \tfrac{3}{4}\frac{p}{P} + \tfrac{1}{4}\cdot\frac{p^2}{P^2}\right)$$

which gives the unit-stress required to rupture the bar when the applied stress ranges from p to P. For security the same factor of safety as for quiescent loads should be introduced, namely 4. Then the working unit-stress is

$$s_w = \frac{e}{4}\left(1 + \tfrac{3}{4}\frac{p}{P} + \tfrac{1}{4}\frac{p^2}{P^2}\right)$$

and under this stress it may be expected that the strain will be safely applied a very enormous number of times within the given range. For example, if e=27,500 pounds per square inch, the following are valves of the rupturing and working strengths of wrought iron for given ratios of the limiting strains.

For p=P	s=55,000	s_w=13,750
For p=½P	s=39,520	s_w= 9,880
For p=0	s=27,500	s_w= 6,875
For p=−½P	s=18,920	s_w= 4,730
For p=−P	s=13,750	s_w= 3,440

The first of these corresponds to the case of dead load where there is no range of stress, the second to the case where the minimum stress is one-half the maximum, both being tension or both compression, and the third to the case where there is no stress under dead load. The fourth and fifth correspond to the case of stress alternating from tension into compression, or *vice versa*, the fourth where the range in one kind is double that in the other, and the fifth where these ranges are equal. It is hence seen to be important that the minimum, as well as the maximum strains, should be computed for members of bridge trusses, and in all cases where pieces are to undergo repeated varying stress.

THE SOLAR TEMPERATURE QUESTION.

By DeVOLSON WOOD, M. A., C. E.

Written for VAN NOSTRAND'S ENGINEERING MAGAZINE.

THE attempted proof by Mr. Gilman —that the intensity of heat emitted by a spherical incandescent body varies inversely as the square of the distance from its center—in the January number of this Magazine, at first sight appears so plausible that it would be almost a graceful act to admit its truth. But, unfortunately, it not only contains some statements the truth of which may be questioned, but it involves principles conflicting with others which are supposed to be well established.

In regard to the proof, Mr. Gilman states that he "has referred me to Captain Ericsson's experimental demonstration." I find no such proof. The principle was *assumed* by that eminent engineer, as stated on page 362 of the November number, in accordance with Newton's assumption, as given in the *Principia*. Although Newton's name carries great weight on all questions upon which he wrote, yet it will not be presumed that his views are to be unquestioned. In regard to heat there was comparatively little known in his day.

Next Mr. Gilman says "after a time the flow of heat from the body will be uniform and each point of the surrounding space will also acquire a constant temperature." Here appears to be a misconception. The temperature of space is a matter about which we have little, if any, definite knowledge. If the ether in planetary space be perfectly diathermanous, heat will pass through it without imparting temperature to it. The temperature may be, and probably is, exceedingly low, while any quantity of solar heat passes through it. The *quantity* of heat passing the concentric spherical shells will be the same, while the temperature may be lower than we are able to measure. Mr. Gilman, however, assumes that the intensity, or temperature, will be directly as the quantity of heat passing a given area—say one square foot—of the spherical shell. This being erroneous his demonstration fails.

The question of temperature is complex, but it is unnecessary to discuss it here, in order to show still further the fallacy. Thus, we assume that it will be admitted that the law of the inverse

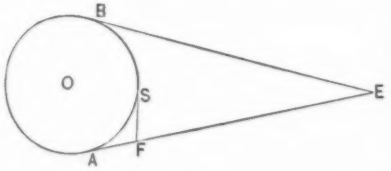
squares would be applicable if the radiant be considered as a mere point. Let *o* be the center of the sun, S a small portion on its surface, and E the position of the

earth. If now, *a* be the intensity of the solar heat at E, the intensity at any distance *x* from S will be

$$a\frac{(SE)^2}{x^2}$$

If $x=o$, this becomes infinite. But if the entire surface be involved and the inverse squares be reckoned from O a finite value would be found for the temperature at S. In other words, according to Mr. Gilman's mode of computation, we will find a less temperature at S when the entire surface of the sun is the radiant, than we will, according to the recognized law when only a small portion of it is the radiant. This is a reduction to an absurdity—both hypotheses cannot be true, and the latter is too thoroughly established to be easily shaken.

Mr. Gilman and Captain Ericsson both assume that heat passes radially outwards as if from the center of the sun; whereas every point on the sun's surface is the center of a hemisphere, through which it radiates heat. Captain Ericsson, on page 363 of the November number of this Magazine, on the hypothesis of radial emission finds that only 0.0658 square inch of the solar surface furnished heat to the 3,130 square inches of his pyrometer; whereas, in fact, it received heat from nearly one-half of the sun's surface.



It is plain from the figure that if the pyrometer be at F it will receive heat from about one-fourth as much surface as if at E, the arc AS being about one-half AB. The nearer a body is to the sun the less will be the hot surface to which it will be exposed. So that while we may admit that the heat received from the small portions of the sun exposed to the pyrometer, varies inversely as the squares of the distance from them, it also varies directly as the sum of those small portions; and since this sum diminishes as we approach the surface of the sun, the law of the inverse square from the center fails. We trust that it will now be seen in what sense the law of Pettit and Dulong is at variance with inverse squares. We repeat what we said in a former article, that the law of the inverse squares does not, in any case, determine the temperature of the radiant; the law of Pettit and Dulong does in some cases at least. If what we have said be correct, it follows that the temperature of the solar surface cannot be determined by applying the law of the inverse squares, and it will no longer be claimed that its temperature exceeds 3,000,000° F., unless deduced by other methods.

[*Note.*—The following remarks bear upon this subject. Professor Zöllner remarks (*Phil. Mag.* 1878, Vol. 46, p. 355), "That there is no proportionality between the heat radiation of a body and its temperature, I have already made clear in a criticism on the method applied by Father Secchi to the determination of the temperature of the sun." Then follows a quotation from Soret. "M. Soret has recently proved by interesting experiments that in fact the heat radiation of a body increases much faster than its temperature, and that consequently the hypothesis made by Father Secchi in his actinometric determination of the temperature of the sun 'the radiation of a body is proportional to its temperature' was inadmissible." Father Secchi found the absolute temperature of the sun to be 2,900,000° F., in regard to which M. Soret remarks, "To control the accuracy of this reasoning, let us apply it to the determination of the temperature of zirconium heated at the oxyhydrogen lamp. We shall find T=45,990° C., a figure absolutely inadmissible, for the temperature of a body heated in the oxyhydrogen-flame is at its utmost 2,500°C.(1,400°F)." It follows from this experiment that the temperature of the solar surface is less than $\frac{1}{20}$ of that found by Father Secchi, or less than 145,000° F. Professor Zöllner found in a computation illustrat-

ing a theory which he had developed that the absolute temperature might be between 26,000° F. and 34,000° F., but he cautions the reader against accepting these as definite values. (*Phil. Mag.*, 1873, vol. 46, pp. 299–301). Rossette concludes that the absolute temperature is not less than 5,500° F., nor much more than 11,000° F. (*Phil. Mag.*, 1879 (2), p. 548).]

THE BLACKSMITH'S ART IN ANCIENT AND MODERN TIMES.

Read before the Society of Architects by ALFRED NEWMAN.

From "The Building News."

THE recent movement in favor of the adoption of wrought-iron work for architectural and domestic purposes, in preference to the hard geometric productions of the foundry, has caused one to wonder why this beautiful art has become superseded by cast iron. As far back as the beginning of the 18th century, castings were intermixed with the wrought work, and, the evil having commenced, the wrought work became gradually exterminated, and castings came entirely into vogue. The florid designs and general pretentious effect producible at a moderate cost captivated the general public, and the smith's art gradually fell into disuse. There are several other reasons why it fell into disuse—notably an Act of Parliament which was passed prohibiting the use of those elaborate and ornamental signs which had made the streets of London so picturesque for a long time, and in which each tradesman outvied his neighbor. The disuse of signs was a really serious blow to the smith, almost as serious as the actual introduction of castings. The gradual general use of coal as a means of fuel did away with fire dogs, grids, spits, and many other items which formed an important part of the smith's business. The rigid register stove and kitchen range now took the place of the formerly picturesque fireplace. These causes, together with the indifferent taste which was growing during the last century, and which even extended far into this, caused many to look upon wrought-iron work with indifference. The smith became a mere laborer; he had lost the love of his art, and the task of now re-instilling an artistic spirit is one attended by great difficulty. Moreover, many architects have so long been accustomed to specify for castings that the cost of wrought iron appears exorbitant in comparison. Furthermore, the enterprising northern firms, whose books of patterns lie close at hand, save many, who care not for detail, a deal of trouble, and, as a consequence, those beautiful gates which are still met with in many of our suburbs are elbowed by work in the worst possible taste. Not unfrequently a classic villa is surrounded by heavy cast-iron railing of so-called early English Gothic style—a style which has been invented by the large manufacturers, and which is quite devoid of the tastes of the period it endeavors to represent. This railing is frequently painted a gaudy red, the effect in many instances being heightened by a liberal display of gold. From the few specimens left us of the architecture of the past centuries, the English smiths had acquired infinite taste, and a perfect mastery over the material on which they worked. The brackets for hour glasses which are still to be seen in many of the country churches, the hinges and the latches, the handles, the font covers and altar rails, &c., are alone sufficient to prove this. In old prints of London mansions, such as Arundel House, Burlington House, Powis House, Montague House, and York House, also, we must not forget to enumerate those fine railings in Great Ormond Street still remaining, which, I am pleased to say are religiously preserved by the owner. No. 5 Bloomsbury Square, Isaac D'Israeli's house, has some fine balusters of 1720; we have good pilasters at No. 45 Lincoln's Inn-fields, and a beautiful panel there. In Westminster Abbey, a well-known example of early ironwork, and some interesting old sword rests in All Hallows, Barking, Church, in

the City, deserve to be better known. Those sword-rests are of Charles the Second's time, and are beautifully worked. Canterbury, Gloucester, Bristol, and York cathedrals boast of excellent work, and in Haddon Hall, Ham House, and other mansions, there are good examples of early domestic ironwork still remaining. Many examples are met with in the provinces of magnificently-wrought gates. All those can only prove how we have deteriorated by the universal use of cast iron. On the Continent, as well as here, a reaction has taken place, perhaps with greater enthusiasm than has been exhibited in this country. For instance, in the Place des Sablons in Brussels, the railings surrounding the gardens have been executed by the leading smiths of Belgium, each having contributed a part in which to display his skill and taste. The result is an effect which must strike the most uninitiated. The smiths here have endeavored to outvie each other by an extraordinary display of the most intricate and difficult treatment, showing a splendid illustration of the mysteries of their craft. This work has been executed by the Government, who have by this means encouraged the spirit of emulation amongst their native smiths. I hope that our Government may pursue a similar policy in some of our public works. But it is in you, gentlemen, the power of fostering this art lies. Your clients are led by you, and to you the public look for that which is best in taste and artistic in treatment. Germany appears to have lost the art more completely than ourselves. Beautiful as the work of the past has been, for the remaining examples in the collection in Munich show the most unique and beautiful in Europe, the modern attempts of Germany in this direction are decidedly failures. And during a recent trip to the principal cities of Germany, I did not discover a single firm who had produced work exceeding in better taste, or, indeed, as good as that which emanates from Birmingham. The liberal use of stamped rosettes, malleable iron, and other tricks for cheapening handwork, have completely destroyed all individuality in the work, and their wrought iron has become cast, as far as taste or effect is concerned. As to French work, it has degenerated into a treatment of polished hoop iron, and is innocent of the hammer of the smith. The Italians, whose splendid reputation in the past would lead one to hope for better things, now devote their skill to the reproduction of sham antiques, and that, too, in the thinnest and flimsiest of material. I have met with no less than three gentlemen, recently, who brought from Italy real antique lanterns, and I have every reason to believe factories for these exist in the neighborhood of Vicenza, the principal city of the iron industries in Italy. In Vienna the movement is taking a right direction, and some really splendid work has been done. Here, again, the State has lavishly introduced wrought-iron work in their public buildings, as the Votive Church; whilst the old gates at the palace of Prince Eugene of Savoy, and some of the balconies in different parts of the new town, show the greatest taste. In the State collection here are also some fine examples of forgings, and also in the St. Stephen's Cathedral. Of Spain, one can only say that the modern Spaniards ignore the forge. In Holland, notably the Hague, no building is erected without the introduction of wrought iron, and much of it is excellent in workmanship and design. At the Exhibition of Amsterdam, recently, there were some really good exhibits of native work. In Hamburg I found some excellent smiths. There is a great taste also arising in America, notably for domestic purposes, and I may remark that the American purchaser shows the greatest appreciation for merit, and has a very sharp eye for defects. And now a word for a land far off, where one would hardly seek for this particular branch of industry—I speak of Japan. I have had the pleasure of seeing some exquisite specimens of ironwork of the choicest possible design and marvelous in workmanship—fire-dogs and irons, lanterns, vases, sword hilts, and other kinds of beautiful objects. Some lanterns from Japan, that I saw recently, show such a Gothic feeling that it causes one surprise as to how they could have emanated from Japanese hands. Having now given a brief glance at foreign work, let us consider what has been done to improve the smith by technical schools of design, or by the much-abused city companies. By the way,

there is a blacksmith's company still extant; but what they have done to foster their art and mystery I have never been able to discover. Now, as to the technical schools, if forges could be erected, superintended by experienced smiths, in conjunction with art classes, I am sure many young men would learn this craft, and not only improve their means, but produce a supply of mechanics which are really becoming needed. Now, as to the English mechanic, we have never had to find fault with his actual work. In accuracy and finish he is all that can be desired, and soundness of his work is undeniable. In this respect an English workman can hold his own against all comers; but when you expect taste, idea or originality, he is most disappointing. He is completely devoid of those qualities. In past times this cannot have been the case. The great skill and taste, together with quaint conceit necessary for producing, for instance, a suit of armor, indicates the high qualities of the smith's calling. There is one great reason, too, which causes a lack of good hands—namely, the gradual but undoubted prejudice against apprenticeships. When it is considered that a strong lad can earn 15s. a week in a factory, his parents or guardians are very loth to apprentice him at all, and a premium is a thing of the past. This lad will destroy his chance of ever becoming an efficient mechanic, and he himself ends in joining the already large army of mediocre workmen who change from shop to shop, and are always out of work. It is also singular to remark that the largely-increased use of tricycles and bicycles has absorbed many of the best smiths we possess. As art workmen they are preferred by the manufacturer from their great appreciation of the niceties of the work. Beautiful as are the designs of many of our architects, in nine cases out of ten it is next to impossible for a smith to execute them, except at a great cost, whereas a similar effect might be obtained by a slight knowledge of the material in which the design has to be made. Junctions are frequently shown where it is impossible for a smith to weld, which induces pinning or riveting, which is not the natural manner in which the smith would execute his work. I may here remark that I shall be most pleased if any member of this society, desiring any practical information, would visit my forge, where I could better illustrate my meaning in this respect. Again, many gentlemen draw their information from the study of Mediæval work, which, I may say, in most instances was executed in a way now no longer necessary or desirable. In Mediæval times a man took his pig of iron, and by a most slow and laborious process drew it down to the size necessary for his work. Thus, in making hinges they were not welded as we do, but were made out of one piece; but now, by means of steam rollers, we are enabled to get ribbons and bars of any size, and so by welding pieces together we can secure the same result without the heavy labor attached to the same process. There are some purists who object to this, and think it necessary to pursue the same process as of old; but it is idle, as the welding implies the perfect junction of the parts. Gentlemen retaining this opinion would find it impossible to distinguish between the old and the new way. As regards the elaboration of the craft, such as flowers, &c., so often exhibited as masterpieces to the eyes of the uninitiated, these are merely manipulations of sheet iron, and could be executed by any decent silversmith, and have nothing to do with the smith's work or legitimate wrought-iron work. There is also a great deal of good smithing that has been spoilt by coming under the hands and files of excellent fitters, who carefully smooth away all traces of the smith's hammer, and produce a piece of ironwork more fitted for a pattern founder than an artistic piece of ornamentation. This overzealous love of finish is a failing that we have constantly to battle with. Now, as to the use of malleable iron which I observe so liberally displayed in the work of firms professing to execute wrought-iron, so far as artistic effect is concerned, cast iron might just as well be used. Its only merit is that it is of a less friable nature. Many orders are secured by firms intending to intermix the decorative parts with this material, which enables them to estimate it at a price which it is impossible to compete with; in fact, hand work and ornamentation produced by this material possesses all

the monotony of cast iron, and should be eschewed on this account. A great deal of ironwork that is spoilt is attributable to the system of inclusive contracts. The quantity surveyor, an inestimable man in most respects, but from whom an artistic or approximation is hardly to be expected, specifies for the amount which he considers sufficient for the smith and his items, such as builders' ironmongery, &c., often includes many pieces of work, such as knockers, handles, &c., which would, if not allowed for, add considerably to the expense of the joiner and stone mason. I am often asked to put 50 ft. or 60 ft. of railings and balusters, with a pair of gates, for £50—a price which would hardly allow for supply of cast iron. Now, another serious reason which prevents much good work from being done, and actually encourages these shifts and contrivances I spoke of elsewhere, is the great idea possessed by many architects of getting a price from several firms, on the competition system. Now, very frequently a person whose tender is the lowest, produces a hard and unsympathetic interpretation of the design, and with a commonplace foundation, and is sometimes an unscrupulous worker, who would sacrifice everything approaching to taste to enhance his profit. This, in fact, is the only course left to him, he having ousted those who might have taken a positive interest in the work. Another very potent reason for the non-encouragement of this system is that many trifling details or additions which might considerably enhance the design, and which can only be ascertained during the progress of the work, must be passed by through the inelastic nature of the contract. We find this peculiarly hard when we have to turn out unsatisfactory work, or bear a loss, and though I am not here pleading for *carte blanche*, I am asking for the same recognition of the smith as of the stone, brick, or wood carver. Now, to recur to the use of wrought iron, as regards domestic work, a serious injury has been done to wrought iron work by designs in the so-called early English and Gothic. Domestic examples of Gothic work exist, and are only found in churches, where trefoils, quatrefoils, triangles, circles, fleur-de-lis, &c., were used as symbolizing Christianity; but it is not to be supposed in Gothic times domestic architecture was treated in this form; hence people have a natural horror of seing a modern corona decorated with these devices in a dining room. But I may say that the few remaining examples of domestic Gothic architecture are entirely free from those ecclesiastical symbols. Talking of ecclesiastical symbols suggests ecclesiastical metalwork, which may be purchased where clerics order their vestments. The corona, the font covers, the hinges, the handles, the altar rails, the pulpit lights, &c., made by the gross, are temptingly arranged in a row, and may be purchased for those of high or low tendencies, much in the same way as mourning may be ordered for overwhelming bereavement or mitigated grief. Why are not these designed by the architects to suit the churches for which they are intended, instead of being left in the hands of dealers. One enterprising firm advertise weekly their list of ecclesiastical abominations, and wind up by stating, "and eagle lecterns from £45." Our old friend, the eagle, having descended so low, I think it high time that he should be abandoned altogether. In spite of what has been recently urged against specialists, it can hardly be expected, gentlemen, that with the anxieties, responsibilities and labor inseparably connected with large building operations, architects can find time to fathom the practical depth of ironwork, which plays a somewhat unimportant part in the ornamentation of the edifice, yet without this practical knowledge the results are seldom, if ever, satisfactory. To observe a junction which would be impossible for the most accomplished smiths to weld, to put rivets where a practical man would put collars, and collars where they would be next to useless, is painful to the initiated, and pleasing in effect to the general critic. The design has to be carried out, but it is a thing of shreds and patches—in fact, not a legitimate construction, and what no smith would attempt if he were freed from the bondage of carrying out the design literally. One of the great charms of Mediæval work is the utter absence of the forced treatment, and it is this which raises the controversy as to who made the designs for these works, the smith or the architect. If made by the smith he

was a man possessed of infinite taste and fancy; and were they made by the architect—well, then the architects of old must have had a practical knowledge of something far beyond anything that can be acquired or expected of the architects of to-day, heavily handicapped as they are by the hurry and competition of the age. It is to be hoped, gentlemen, and it rests with you more than with any of my craft, that we may arrive at a higher stage of perfection in this art than has been yet attained. It would be rather humiliating to suppose that you had only attained the standard of past workers in this age with all the advantages we possess. I hope we shall not be content with achieving the highest qualities of Mediæval work, but that we may yet far exceed them.

THE ORIGIN AND REMOVAL OF AN OBSTRUCTION IN THE DANUBE.

By E. GARTNER.

From Abstracts of the Institution of Civil Engineers.

During the construction of the North-Western Railway Bridge across the Danube, in 1870, and after the caisson for No. 2 Pier (which was attached by chains to two floating stages or platforms) had been sunk in its proper position, and the pneumatic foundation of the pier had commenced, a very strong flood accompanied with much ice came down the river and broke one of the mooring chains. The staging consequently shifted its position and, together with the attached caisson, would have been carried down stream, and probably have greatly injured, if not destroyed, the Tabor and Northern Railway bridges (both wooden structures), had not the engineer in charge knocked out the bolts of the chains and thus set free the caisson, which sunk and took up a position oblique to its original site, and at its nearest point about 17 feet distant from it.

The two stages subsequently sprung a leak and sunk, and orders had been given for their being fired into and destroyed—for they could not be approached on account of the ice—when another flood occurred which carried them, fortunately, clean through the Tabor and Northern Railway bridge openings, though for a time the latter bridge was endangered. It was at first proposed to lift the caisson and its appendages bodily, and a special contrivance, a drawing of which is given, was designed with this object, but little was accomplished. A diver was also engaged to recover the chains by which the caisson had been suspended from the floating stages, but the force of the current prevented his working. This method of removing the obstruction was therefore abandoned, and its complete destruction by blasting with dynamite resolved upon. It should be mentioned that during the above operations the construction of the bridge was steadily proceeded with, and was completed in eighteen months, or three and a half months within the contract time.

The first experiments with dynamite under ice proved that charges of even 9 lbs. might be used without seriously endangering the stability of No. 2 pier, which, as before stated, was at its nearest point 17 feet distant from the sunken caisson, but also showed that, owing to the intense force of the current below, special precautions were necessary in laying the charges, and these took too much time. A stop was consequently put to the blasting operations, and the matter referred to a committee.

The Committee proposed that the river-bed should be dredged out and the caisson buried at such a depth as to comply with the order of the River Commissioners, viz., to have 10 feet of water clear for navigation. This necessitated the excavation of a pit about 25 feet below the surface of the water, and the construction of a special dredging machine to work at such depth. The work commenced in the autumn of 1872, and by the middle of November the required depth was almost

reached, but it could not be maintained as the pit continually filled up, and, after about four times the actual cubic capacity of the caisson had been dredged out and other difficulties encountered, this plan was abandoned. A mechanical destruction of the caisson by cutting it up into pieces was then proposed, but rejected on account of the cost, and finally recourse was had again to blasting with dynamite, and special experiments were made as to the most suitable strength of the charges and the best methods of laying them. Captain Lauer of the Engineers, was placed in charge of the operations, and he designed a special blasting vessel, with arrangements for laying the charges exactly and expeditiously in position, as this was found to be the chief difficulty in the previous experiments owing to the strength of the current. This vessel was 80 feet long and 12½ feet broad, and could be fixed in any required position by hauling on chains attached to two bow and two stern anchors.

A wooden platform projected about 16 feet over the stern, and at the end of this was a movable framework or grating to guide the rod carrying the charge, the upper end of which passed through a ring or staple attached to the cross-piece of a timber frame fixed to the platform, to which also was fastened a pulley, over which ran the chain for lowering or raising the rod.

The guide-rod was made of iron gas-pipe 2½ inches inside diameter, and 1½ inch thick. The lower end was split up for about a foot to receive a stick 5 or 6 feet long which was there securely fastened, and at its lower end carried the box containing the charge, which was fired by electricity from the blasting-vessel. The rod was then drawn up, a new stick and fresh charge attached, and it was then let down again and so on. At first, charges of ½ lb. only of dynamite were used, but afterwards it was found that charges of 1 lb. and even 1½ lb. could be used with safety, and the work accordingly made great progress.

Altogether two hundred and twenty-three charges were fired, involving a consumption of 187 lbs. of dynamite. The quantity of material removed was 53 cubic yards, which gives $\frac{187}{53}=3\frac{1}{2}$ lbs. per cubic yard. The work occupied the officer in charge, with seven or eight men, twenty-two days, viz., from 4th to 25th November, 1873, and, inclusive of salary and wages, purchase of dynamite, &c., cost about £320, or say £6 per cubic yard.

As dynamite readily freezes at 50° Fahrenheit, and during November a continual low temperature prevailed, it was necessary to soften it by warming. A full description with sketch, is given of the warming apparatus, and also of the fuse for firing the charge. Of the two hundred and twenty-three charges fired—

			Lbs.
91	contained	½ lb. dynamite =	45½
114	"	1 " " =	114
18	"	1½ " " =	27
	Total.....		186½

DANCHELL'S ELECTRIC RAILWAY.—There is on exhibition at the Westminster Aquarium a working model of a new electric railway for which very considerable advantages are claimed by the inventor, Mr. Danchell. The feature which distinguishes it from previous attempts of the same kind is that the locomotive and vehicles run between a pair of rails placed vertically one over the other, the lower carrying the weight and the upper serving as a guide to prevent the vehicles from falling over sideways, and also, in some instances, increasing the adhesion of the locomotive. Each vehicle has two wheels, one before the other. These wheels are not flanged, but are kept on the track by eight guide rollers, two running against each side of the upper rail and two against each side of the lower rail. The electric motor carries on its spindle a small friction pulley, situated between the two driving wheels of the locomotive. These wheels are carried in sliding bearings and can be set up to obtain a sufficient pressure against the friction pulley, so that the rotation of the motor is imparted to them. For lines with steep gradients, a small wheel is fixed over each driving wheel in such a way that it has a constant tendency to jam itself between the wheel and the upper rail and thus increase the adhesion of the locomotive. The rails act as the conductors for the current, which enters the motor from one of them and leaves it by the other. It is claimed for this railway that it will run with very small friction, and that exceedingly high speeds are possible without danger, but it is difficult to find any argument for putting an electric locomotive on a single rail which is not equally applicable to a steam locomotive, while the safeguard afforded by an overhead rail is as available with one kind of carriage as another. An engineer who put forward such a plan with any existing form of traction would expose himself to derision, and we fail to see that the use of electricity as a propelling power alters the conditions of stability under which a railway works. As to the electrical part of the scheme it appears devoid of novelty, and whatever advantages exist in the Danchell railway are to be found in the use of a single track and a steadying overhead rail.

EVAPORATION OF WATER FROM AND AT 212° FAHRENHEIT.

By RICHARD H. BUEL, C. E.

Written for Van Nostrand's Magazine.

In order to reduce the results of boiler trials to a common standard, for the purpose of comparing them with each other, it is usual to calculate, from the evaporation under the actual conditions of test, the equivalent evaporation, or the evaporation which would have been obtained if the temperatures of feed water and steam had each been 212° Fahrenheit.

Thus, if E represents the number of pounds of water evaporated per pound of combustible at a pressure P, from a temperature T; H, the number of British thermal units per pound of steam evaporated under these condition; and L, the number of British thermal units per pound of steam evaporated from and at 212°; the equivalent evaporation per pound of combustible will be

$$E \times \frac{H}{L}.$$

The quantities, H, and L, are to be taken from a table of the properties of saturated steam; H, being a variable depending upon P, and T; and L, a constant. Most of the steam tables in use are professedly based on the experimental results obtained by H. V. Regnault, and published in the "Mémoires de l'Académie Royale des Sciences de l'Institut de France. Tome XXI. Paris, 1847." Hence, one might reasonably expect that the quantity L, would be the same in all modern steam tables; but this is not the case. It may be interesting and useful to examine the variations, especially if this examination shall throw any light upon the actual value of the constant L, as determined by Regnault.

In the "Report of the Committee appointed to Test Steam Boilers at the American Intitute Exhibition, 1871," the results are reduced to equivalent evaporation by the aid of a constant, L=966.6.

In the "Reports of the committee of the Franklin Institute on the Horse Power of Steam Boilers, Philadelphia, 1874," and in the boiler tests made at the 27th Exhibition of American Manufacturers, Franklin Institute, 1874, the value of the constant, L, was taken as 966.

In the Centennial boiler tests, Philadelphia, 1876, the reductions to equivalent evaporation were made with a constant, L = 965.7.

Results of equivalent evaporation obtained in boiler tests are frequently calculated to three decimal places; so that the value of the constants used in the calculations is a matter of some importance. This may be illustrated by an example.

In the report of a certain boiler trial, it was stated, that the evaporation produced by the consumption of 12,114.5 pounds of combustible was equivalent to 131,673,893 British thermal units; and using a value of L=965.7, the equivalent evaporation per pound of combustible was found to be 11.255 pounds. If L=966, this equivalent evaporation becomes 11.252 pounds; and for L=966.6, the equivalent evaporation is 11.245 pounds.

The values of L, as given in several well-known steam tables, all of which tables are professedly calculated from Regnault's results, are shown in Table I. It appears from this table, that Regnault himself makes L=965.7; and from this fact, it might be inferred, that any one who presented a table containing a different value of L, did not correctly report Regnault's results. But a distinction must be made between the results calculated by Regnault, and the actual results shown by some of his experiments. Regnault, in his report, describes in detail the manner in which he conducted his various experiments, gives all the observations, and explains his method of calculating the results from the observations. After calculating the several results of a series of experiments, he determines the equation of a curve which, in his opinion, agrees most closely with the series of results. By the aid of the equations thus determined, he calculates tables intended to show the results of his several series of experiments; and it is from these tables, apparently, that most of the mod-

ern steam tables have been deduced. Whether or not the calculated results are more accurate than the results of observation, will be briefly discussed.

Referring to Table I, it will be seen that, with one exception, all of the steam tables quoted give the same value for the total heat of evaporation above 32°; and

TABLE I.

BRITISH THERMAL UNITS IN A POUND OF STEAM EVAPORATED FROM AND AT 212° FAHRENHEIT, AND THERMAL UNITS IN A POUND OF WATER AT THE TEMPERATURE OF 212° FAHRENHEIT.

Authority.	Latent Heat of Evaporat'n.			Heat of Water above 32° Fahrenheit.	Total Heat of Evaporation above 32° Fahrenheit.
	Internal Latent Heat.	External Latent Heat.	Total Latent Heat. L.		
H. V. Regnault, in "Mémoires de l'Académie Royale des Sciences. Paris, 1847." C. T. Porter, in "Treatise on the Richards Steam Engine Indicator. New York, 1874."	——	——	965.7	180.9	1146.6
W. J. M. Rankine, in "A Manual of the Steam Engine and other Prime Movers. London, 1866."	——	——	966.1	180.5	1146.6
R. H. Buel,* in Weisbach's "Heat, Steam and Steam Engines. New York, 1878."	893.894	72.175	966.069	180.531	1146.6
B. F. Isherwood, in "Experimental Researches in Steam Engineering. Philadelphia, 1865."	893.666	72.034	965.7	180.9	1146.6
W. P. Trowbridge, in "Heat as a Source of Power. New York, 1874."	893.34	72.36	965.7	180.9	1146.6
R. H. Thurston, in "The American Cyclopædia. New York, 1876."†	(1) 892.9	72.3	965.2	180.9	1146.1
	(2) ——	——	966.6	180.	1146.6
	(3) ——	——	965.988	180.612	1146.6

* Also in "Appleton's Cyclopædia of Applied Mechanics. New York, 1880." And in Röntgen's "Principles of Thermodynamics. New York, 1880."

† The quantities in lines (1) and (2) are copied from two tables that are contained in the article quoted; and the quantities in line (3) have been calculated by the writer from two formulas in the article for the latent and total heat of steam at any temperature.

that the different values of L, in Table I, are due to variations in the number of British thermal units required to raise the temperature of a pound of water from 32° to 212°. Regnault made forty experiments on the specific heat of water, at temperatures varying from 225.86° to 374.648° Fahrenheit, using a calorimeter in which water at a high temperature was mixed with cold water, and the resulting temperature noted. From these experiments, he concluded that the mean specific heat of water was 1.005, between 32° and 212°; and 1.016, between 32° and 392°; and from these two assumptions, he determined the constants of a formula for calculating the heat in thermal units required to raise the temperature of a given weight of water from 32° to any higher temperature, T. By means of this formula, he calculated a table showing the specific heat of water from 0° to 230° Centigrade. It seems probable, as will presently appear, that the data selected by Regnault to establish his formula were not justified by the experimental results.

At a meeting of the Royal Society of Edinburgh, Dec. 15, 1851 (see Transactions of that Society, vol. XX.), Prof. Rankine read a paper entitled: "On the Computation of the Specific Heat of Liquid Water at Various Temperatures, from the Experiments of M. Regnault. Correction of M. Regnault's Experiments for the Effect of Agitation."

The nature of the correction made by Prof. Rankine is explained by the following extract from his paper:

Table II.

Regnault's Experiments on the Specific Heat of Water at Different Temperatures.

Original temperature of water in Calorimeter, Fahrenheit Degrees. T_1.	Final temperature of water in Calorimeter, Fahrenheit Degrees. T_2.	Temperature of water admitted from boiler into Calorimeter, Fahrenheit Degrees. T_3.	Ratio of Mean Specific Heat of water between T_2 and T_3 to its mean Specific Heat between T_1 and T_1.			
			As Calculated from Experim't.		As Calculated by Formula.	
			By Regnault.	By Rankine.	Calculated by writer, from Regnault's Formula.	Calculated by Rankine, from his Formula.
53.546	69.386	226.022	1.00384	1.00375	1.00594	1.00409
47.102	63.86	228.722	1.00680	1.00655	1.00629	1.00414
55.328	79.354	319.532	1.00871	1.00779	1.01170	1.00959
48.11	75.092	342.842	1.01140	1.01019	1.01333	1.01055
55.346	83.642	367.718	1.01581	1.01419	1.01533	1.01248

Table III.

Heat of Steam and Water, in British Thermal Units, at Different Temperatures.

Temperature of Steam, Fahrenheit Degrees. T.	British Thermal Units per Pound.						
	Rankine.			Regnault.			
	In water, above 32° Fahrenheit H.	Latent heat of Evaporation. L.	Total Heat of Evaporation above 32° Fahren. H+L.	In water, above 32° Fahrenheit H'.	Latent heat of Evaporation. L'.	Total heat of Evaporat'n above 32° Fahrenheit.	
						H'+L'.	As Calculat'd from Formula.
32	0.	1091.7	1091.7	0.	1091.7	1091.7	1091.7
50	18.	1079.19	1097.19	18.0036	1079.1	1097.1036	1097.1
68	36.	1066.68	1102.68	36.018	1066 68	1102.698	1102.68
86	54.018	1054.152	1108.17	54.0468	1054.26	1108.3068	1108.26
104	72.036	1041.624	1113.66	72.0918	1041.66	1113.7518	1113.66
122	90.054	1029.096	1119 15	90.1566	1028.88	1190.0366	1119.06
140	108.108	1016.532	1124.64	108.2466	1016.46	1124.7066	1124.64
158	126.18	1003.95	1130.13	126.378	1003.68	1130.058	1130.04
176	144.252	991.368	1135.62	144.5076	991.08	1135.5876	1135.62
194	162.378	978.732	1141.11	162.6858	978 3	1140.9858	1141.02
212	180.522	966.078	1146.6	180.9	965.7	1146.6	1146.6
230	198.72	953.37	1152.09	199.1538	952.92	1152.0738	1152.
248	216.918	940.662	1157.58	217.4508	940.14	1157.5908	1157.58
266	235.188	927.882	1163.07	235.7946	927.18	1162.9746	1162.98
284	253.512	915.048	1168.56	254.187	914.4	1168.587	1168.56
302	271.872	902.178	1174.05	272.6316	901.26	1173.8916	1173.96
320	290 268	889.272	1179.54	291.1338	888.48	1179.6138	1179.54
338	308.754	876.276	1185.03	309.6936	875.16	1184.8536	1184.94
356	327 276	863 244	1190.52	328.3164	862.2	1190.5164	1190.52
374	345.87	850.14	1196 01	347.0022	848.88	1195.8822	1195.92
392	364.5	837.	1201.5	365.76	835.74	1201.5	1201.5
410	383.256	823.734	1206.99	384.588	822.24	1206.828	1206.9
428	402.048	810.432	1212.48	403.4916	808.92	1212.4116	1212.48
446	420.912	797.058	1217.97	422.4744	795.42	1217.8944	1217.88

"The discovery by Mr. Joule of the fact, that mechanical power expended in the agitation of liquids is converted into heat as the visible agitation subsides, renders a certain correction necessary in calculating the results of experiments on specific heat in which such agitation has occurred.

"Of this kind are the experiments of M. Regnault on the apparent specific heat of liquid water at different temperatures. Water at a high temperature, T_2, was emitted from a boiler into a calorimeter containing water at a low temperature, T_1, and the resulting intermediate temperature of the whole mass, T_3, was used as the means of calculating the ratio of the mean specific heat of water between T_3 and T_2 to its mean specific heat between T_2 and T_1. Now, the upper part of the boiler contained steam at a high pressure, so that the hot water was expelled with great force. The vis-viva thus communicated to the water, having been converted by fluid friction into heat, ought to be allowed for in computing the results of the experiment."

After determining the formula for calculating the results from Regnault's data, Prof. Rankine arranges several of the experiments in groups each consisting of experiments in which the temperatures were about the same, and calculates the mean specific heat for each group. From these results, he determines the constants of an empirical formula. Table II. gives the principal data of the experiments selected by Prof. Rankine, and the specific heat, as calculated from these experiments both by Regnault and by Rankine. From this table, the reader can judge, which of the two empirical formulas—Regnault's or Rankine's—most nearly represents the results of the experiments, and whether or not the assumptions on which Regnault's empirical formula is founded are justified by the experiments.

Having calculated a table of the quantities of heat required to raise the temperature of a pound of water from 32° to higher temperatures, T, Regnault states that the differences between these quantities of heat and the corresponding total quantities of heat above 32° per pound of steam (which latter quantities are given in a preceding portion of his report,) constitute the quantities of latent heat per pound of steam, at the different temperature. Table III. contains the latent heat of steam at different temperatures, as given in Regnault's report, and other quantities of heat, as indicated by the several headings. This table is designed to still further illustrate the fact that the calculated results in Regnault's report are, in some cases, less reliable than the experimental results.

In table III., the column headed $H+L$, contains the total quantities of heat in steam at different temperatures, as calculated from Regnault's formula; and the last column of the table contains the results of Regnault's calculations of the same quantities by the same formula. Wherever there are differences between corresponding quantities in the two columns, these differences are due to errors in Regnault's calculations, or to misprints, as any one can easily ascertain, by observing that Regnault's formula requires the successive differences to be $0.305 \times 18 = 5.49$ British thermal units.

The column headed L′, contains the quantities of latent heat, as given by Regnault; and the column headed, H′, contains the heat of water, on the same authority. From these two columns, the column headed $H'+L'$, has been calculated, and it will be seen that the quantities in this column do not in all cases agree with the corresponding quantities in the last column of Table III.

For the reasons stated in this article, it seems proper to conclude:

1st. That in reducing the results of boiler tests to equivalent evaporation, the reduction should be made with the constant, $L=966.1$, to agree with the results of Regnault's experiments.

2d. That the formulas given by Prof. Rankine, for the specific heat of water and latent heat of steam, at different temperatures, more accurately represent the results of Regnault's experiments than the formulas given by Regnault himself.

THE producers of petroleum on the western shore of the Caspian Sea, it is said, have been seriously contemplating laying a pipe-line entirely across Persia to the Persian Gulf. If this were done, they claim that they would have the Asiatic market to themselves. This pipe-line would have to be something more than seven hundred miles long to reach the coast; and as it would for a long distance pass through a territory of savage Kurds, and other Nomadic tribes, it is feared that it could not easily be kept in operation.

EMERY WHEELS AND EMERY WHEEL MACHINERY.*

By W. O. ROOPER.

From "Iron."

Emery is a mixture of corundum and oxide of iron; corundum itself is alumina, with a little silica. Sapphire and ruby are corundum in its purest form, slightly tinged with iron oxide. In a less pure state corundum is found in many places, and is then valuable only for commercial purposes. The emery beds of most importance are those situated in Turkey and Asia Minor; considerable quantities of emery are found near Smyrna and Ephesus. The material takes its name from Cape Emeri, a promontory in the Isle of Naxos, where there are considerable deposits. In 1871 large beds of corundum were discovered in North Carolina, their existence having been betokened by the presence of numerous water-worn pebbles in the beds of the adjacent rivers. These beds have been worked commercially, and the corundum extracted, crushed, and used for grinding and polishing. Emery is obtained from surface workings, and the presence of the emery is generally indicated by the dark red color of the ground above it. The prospectors strike steel rods sharply into the ground where they expect the existence of emery, and by examining the points of the rods can easily detect its presence. The mineral is broken up into lumps weighing about 1 cwt. each. If hard to break, a fire is lighted around the refractory lump, and on cooling, blows are resorted to again. The lumps are then carried to the coast by railway or on muleback, and the material reaches England chiefly as ballast; thus freight is an insignificant item in the cost. The Turkish and Greek Governments generally let the right to raise and dispose of the emery to English capitalists. The specific gravity of emery ranges from 3.75 to 4.28, and the color from dark grey to black; there is an impure variety of corundum blue grey to brown in color. Much of the commercial emery is artificially colored, and is often mixed to a small extent with ground iron slag; some buyers insist upon the adulteration. Analysis of emery shows that it is composed of from 60 to 80 per cent. of alumina, 8 to 33 per cent. of iron oxide, together with a small quantity of lime water and silica. Taking sapphires as a standard at 100, corundum from the Carolina mine has an abrasive power of from 90 to 97, and the best Naxos emery from 40 to 57 only. This would make it appear as if corundum were far superior to emery for grinding purposes. However, this is not the case, on account of the peculiarity of the fracture of the latter. Every grain of emery breaks with a rough conchoidal surface, and presents numerous sharp points, be the lump large or small; even flour emery exhibits this markedly when examined under the microscope. Corundum on the other hand, although breaking into pieces with many sharp points, exhibits also plain and curved surfaces. It is owing to this that corundum is not more extensively employed in the manufacture of grinding wheels. Thus, emery will cut its way into the material operated on, while corundum will grind and tear, and only perform the work in consequence of its being of a harder nature.

The next point to consider is the preparation of emery on its arrival in this country. It is first treated in the emery mills; stone crushers reduce the large lumps to pieces about the size of a hen's egg, and these in turn are reduced in a stamping mill, or are ground in a horizontal revolving mill with cast-iron circular grinding plates. Naturally the life of these plates is not long, and frequent renewals are necessary. The fragments of emery are then passed between chilled cast-iron rolls and ground or crushed again, then sifted through sieves. During these operations a portion of the emery is separated from the lumps in the form of dust, which collects on the top of beams and other places. This emery dust is all carefully preserved, and, under the name of flour emery, is useful for

* Paper read and discussed at a meeting of the students of the Institution of Civil Engineers; awarded a Miller prize.

polishing. Levigation is another process employed for separating the coarse grains from the fine emery. Six cylinders, about 3 feet high, are ranged in a row, and are in communication with one another at the top by means of metal pipes. Water mixed with emery from the rolls is introduced into the first vessel. The heavy grains sink, while the lighter ones, remaining in suspension, pass over into the next vessel. The process is repeated throughout the range, the last vessel containing the finest emery. There are now in this country a fair number of emery mills, but in America the trade is of greater magnitude and more importance. Emery crushers generally manufacture emery cloth as a branch of their business, as also the flour emery. The chief use of flour emery is for making knife polish, of which enormous quantities are sold. By far the largest demand for grain or crushed emery is for the manufacture of emery grinding-wheels, which of late years have become familiar objects in most engineers' shops. Emery-wheel makers in this country do not, as a rule, crush emery. During the last ten years many classes of emery wheels have been introduced.

The emery wheels best known in England now are the "silicate," or "grey" wheel, the "vulcanite," or "black" wheel, "shellac," or "red" wheel, the "union" wheel, and the "tanite" wheel. The silicate wheel was invented by Mr. Frederick Ransome, Assoc. Inst. C. E., who has perfected the method of manufacture. He employed silicate of soda as the base of the wheel; emery wheels were made for some time by the Ransome Patent Stone Company, in conjunction with their artificial stone and grindstone business. The process consists first in the preparation of the silicate of soda. Beach flints, mostly brought over from France, and used in preference to English flints on account of their being associated with less chalk, are placed in a steam-jacketed boiler; caustic soda is added and steam turned on. After some hours the dissolution of the flints is complete, very little solid residue being left. The liquid is then allowed to settle and run into a tank, where it is evaporated down to a consistency much like that of treacle, but as clear as sherry. This will remain fluid if properly made. Emery of the required degree of fineness is united with this silicate of soda in a mill and a thorough mixing obtained; this "pug" is then pressed into moulds by hand pressure. The disc produced would naturally harden by itself in time, but in order to save time it is baked, and is then complete and ready for use. The manufacture of black or vulcanite emery wheels requires heavy and costly machinery. The base is india rubber, oxidized oil, or other similar material. This is intimately mixed with the emery in steam-heated rolls (horizontal hollow cylinders); afterwards calendered to exact dimensions, and squeezed into moulds in a powerful hydraulic press. The discs are then cured in the same manner as vulcanized india-rubber goods, after which they are ready for use. What is known as the red wheel is made with shellac as a base, and although the process is now considered old-fashioned, excellent wheels for some classes of work are the result. Shellac is heated in an iron pot; the emery, which has been previously heated is introduced, and the whole is well mixed by hand with iron spoons. The pug is then put into moulds and squeezed in a hydraulic press; afterwards the discs are baked at a low temperature. The tanite and union emery wheels are made in America; the methods employed in their manufacture are kept secret and jealously guarded. In the tanite wheel a solution of leather, and in the union wheels oxychloride of magnesium, are the binding materials. The tanite wheel has the reputation of being the best made in America.

Emery wheels have been described as circular files which never grow dull. As previously mentioned, the emery grains throughout the wheel retain their cutting power; and if these grains are cemented together with a proper binding material, an emery wheel can be worked until 90 per cent. of its original weight has been worn off. A file is useless before 5 per cent. of its weight has been used up, and when being worked is driven by manual labor at a speed of 90 feet per minute. An emery wheel penetrates without difficulty into the hardest metals, some wheels even cutting chilled iron or hardened steel more easily than soft iron, and it is

driven by steam at a peripheral velocity of about one mile per minute. In using emery wheels successfully, it must be borne in mind that as the wheel wears away the revolutions per minute must be increased, so that as nearly as possible the same surface speed may be maintained upon the periphery of the wheel. The economy of emery wheels in the operation of fettling or trimming castings is very marked, and this relates not only to economy in tools, but also in the saving of time. American foundries, and many English ones, are well supplied with emery fettling machines. An emery wheel keeps its size and shape far longer than a grindstone, and very little practice is required to use it successfully. It is a common thing to see a grindstone, 24 inches to 18 inches in diameter and 18 inches wide, slowly rotating in a trough, while men push and shove their tools against it to make any impression. It has been stated by an eminent firm of engineers in London that an emery disc as a tool-grinder lasts out six 4-feet grindstones, and only requires trueing once a month, against the weekly trueing up of a stone. They calculate the cost of keeping an emery wheel tool grinder in order as one-fifth of that formerly expended upon the maintenance of grindstones, and the time occupied in grinding tools one-half of that formerly required. In grinding tools, if very large quantities of metal have to be removed, it is best to grind them quickly, and to ignore their temper, rehardening them afterwards; but if only slight amounts, then the grinding should be gentle, and their temper will not suffer. Carpenters' planes can be ground by an emery wheel with ease after a little practice.

In this country many persons have failed in the use of the emery wheel, owing to insufficient knowledge. Experienced men, who will take many precautions in fixing a lathe or planing machine, will erect an emery machine anyhow, and then allow it to be used by anyone. A very simple machine is sufficient, but it must be rigid, on a good foundation, having long bearings protected from dust, and must be so steady when in use as to be absolutely without tremor or vibration. A wheel should be mounted true and between two washers, screwed up moderately tight, never by driving the wheel on to a square spindle with a mallet, and tightening up the nut with a long-handled spanner. Care should be taken to run the wheel so that the nut tends to tighten itself upon the spindle. Attention should be given to keep the emery wheel true. In large factories one man should have charge of all the emery wheels, and should make his rounds at intervals to true the emery wheels with a diamond tool. This tool consists of a small black diamond set in the end of a ½-inch steel bar, about 8 inches long, fastened on a handle. In trueing, the rest is fixed close to the wheel, and on a level with its center. The diamond tool is then held firmly on the rest, and the point is gradually worked backwards and forwards until the projecting parts are removed and the wheel runs true. The difference in working with a true wheel and one running out of truth can hardly be imagined by those unaccustomed to emery-wheel grinding. In the latter case grinding is a disagreeable duty, and the jar and vibration render the task of holding on the work very irksome. It is not by heavy pressure that the most and quickest grinding will be effected; the article merely requires holding up well and constantly against the wheel. Intelligent users soon get accustomed to feel the bite. The most economical speed for emery wheels is about 4,000 to 5,000 feet of circumference per minute. Some wheels are driven faster than this, and with good results; but owing to the jar which occurs if the wheel runs out of truth in the slightest degree, and to the necessity of such rigid foundations, a speed of 5,000 feet is seldom exceeded with success. There is, however, no doubt that the faster a wheel is run the more is the work accomplished. Too much pressure on certain classes of emery wheels induces heat; and the melting of the india-rubber or other substance used as the cementing medium produces a glaze upon the cutting surface. By changing the metal being ground, as, for example, copper after iron, this glaze may generally be removed. In the case of wheels made with silicate of soda, or oxychloride of magnesium as the cementing medium, pressure only raises the temperature of the work, and does not injuriously affect the wheel. Experi-

ments have been made with a view of ascertaining the utmost speed at which an emery wheel would run without bursting, but all wheels tried have stood the utmost test applied. On the rare occasions when wheels have burst, the cause has invariably been traced to unsteady bearings, improper adjustment of the wheel in the first instance, or an article being jammed between the wheel and the rest. But it is well known that far fewer accidents arise from the bursting of emery wheels than from the bursting of ordinary grindstones. It must not be forgotten that as different shapes and varieties of steel tools are necessary for different operations upon a lathe or planing machine, so different classes of emery wheels are required for different purposes, and it is the best economy thus to apply them. One class of wheel should be kept for one class of work whenever practicable. Wheels can be made hard or soft, rough or smooth, slow cutting or quick cutting; as a rule, fast-cutting wheels have a rough surface, and slow cutting a fine one. As in the case of an ordinary grindstone, the faster a wheel cuts the faster it will wear away. A wheel can be made so hard, that after six months' usage no wear to speak of will have taken place; but the amount of work such a wheel would have turned out would be infinitesimal, compared with that which a softer wheel would have done, and the money and time lost in working the hard wheel would have purchased many soft ones.

In the machinery for mounting emery wheels, first comes the tool grinder, a common object in large works, and invaluable for putting a fine cutting edge on tools, grinding them to template, or reducing them quickly. The emery wheel, generally of a fine grade, is mounted in a small cast-iron trough cast on a pedestal, extra long bearings are provided, and a cap which will completely cover the upper half of the wheel, excepting 3 or 4 inches where the rest is fixed, a little above the center of the wheel level. A continuous water supply is provided by means of a small pump, and a tank within the pedestal. The cap serves to keep the water from flying off the wheel whilst rotating. The emery surfacing machine has only been introduced lately. It is probably an English idea, although modifications have been introduced from America. A cast-iron box, with a top movable in a vertical direction, has long bearings across it. In these runs the spindle, upon which the emery wheel is fixed. The movable top of the box has a hole cast or ground in it, just large enough to admit a small portion of the periphery of the emery wheel to protrude, so that the wheel is otherwise entirely boxed in. A small fan revolves at the bottom of the box, and collects all the dust and cuttings which follow the wheel, thus helping to keep the surface of the table clean. By means of a screw adjustment the table can be raised or lowered, and a greater or less amount of wheel exposed. The article to be ground is passed backwards and forwards on the table top over the protruding part of the wheel. As the table is exactly true, only the projecting parts of the article can be touched by the emery wheel, and thus flat surfaces are rapidly attained. A steel key, which would take a fitter half an hour to complete, can be ground true by an emery wheel in five minutes. The top of the table should consist of a ground chilled plate. Slide bars for locomotive engines, after being case-hardened, are generally ground true in a special machine. The bar is cramped down in a horizontal trough which moves backwards and forwards under the emery wheel. This, with its spindle, runs at right angles to and above the trough. The bearings are supported by horns from the machine standards. The emery wheel spindle, in addition to its rotatory motion, has a cross travel, so that during the forward and return journeys of the slide bar every portion of it comes into contact with the emery wheel. The cloth has a reciprocating motion like a planing-machine table. Dust from the wheel and slide bar gets into the bearings and soon wears them down, so that great attention is necessary. Mr. W. Adams, M. Inst. C. E., of the London and South Western Railway at Nine Elms, put in some metallined bearings which have answered admirably, and have run without oil or renewal for four years. During that time his machine has surfaced seven thousand and forty slide bars, and the wheel which was twenty-four inches in diameter at starting, has only worn down to twenty-two inches.

The lateral travel of the machine is 3½ inches, and it moves across once to about every thirty revolutions of the spindle. Crank pins, after case-hardening, are trued up at the Nine Elms works by means of emery wheels. A pin is placed in an ordinary lathe, and driven at a low speed. A 14-inch by 2-inch emery wheel is fitted up solidly on the slide rest, and is driven off a wide drum on a counter shaft, the small pulley on the emery-wheel spindle being provided with flanges to keep the driving strap on. Case-hardened and chilled rolls are trued up in the same manner, and this method of removing the superfluous metal from such hard material has proved very successful, not the least advantage being that no stoppages for fettling tools are necessary. In railway and repairing shops, where new ends are brazed upon old boiler tubes, emery wheels are useful for removing the scurf from the joint, and reducing it to the required diameter.

Pulley grinding is another common use to which emery wheels are put. Cast-iron pulleys are often ground just so that their hard surface is removed, and a tool can enter without being injured immediately. Wrought-iron pulleys are almost invariably ground in a large surfacing lathe, the emery wheel running on the rest and being driven from an overhead drum. This is no doubt an economical way of getting up wrought-iron pulleys, and through its adoption lighter iron can be used for the rim of the pulley than if it were going to be turned true with a tool. The long knife emery-wheel sharpener is for grinding and sharpening the knives used by paper makers, tobacco cutters, and bookbinders. The knife is fixed in a slide rest, which has a self-acting rectilinear motion in front of the emery wheel (generally here a large-sized one), which runs in long bearings at the back of the machine with its spindle parallel to the knife. As the knife is only ground by the periphery of the wheel, a certain concavity dependent upon the size of the wheel is produced upon the edge of the knife. This concavity is so small that it is ordinarily disregarded. In an American machine recently introduced this defect is remedied by using an emery cup wheel, fitted on to the end of the shaft, which runs at right angles to the knife, and thus performs the grinding with its face and produces a flat surface. The ordinary fettling machine for foundry and yard work consists of a heavy vertical cast-iron box, 2 feet by 3 feet by 2½ feet high, with two long bearings on the top, and a steel 1¾-inch spindle running in them. The driving pulley is often keyed on the spindle between the bearings, and two heavy emery wheels overhang on each side. Sometimes one emery wheel is fixed in the middle of the machine between the bearings and pulley outside. Such a machine is invaluable for dressing heavy castings, and is also useful in girder work for taking off the arisses left by the saw, and for cutting the bevel of the T-iron stiffeners. A smith takes from three and a-half to four minutes to cut the bevel of a 3-inch by 4-inch T, and a man can grind off the bevel with an emery wheel in from one to one and a-half minute, saving at the same time the wages of a striker, and the cost of repairing sets. Smaller fettling machines are made for lighter work, and these are generally bolted down to the bench, or on to a stand made for them. Agricultural and other engineers who have a variety of small articles to get up find emery wheels very useful.

Coming to lighter work, the emery tape machine is a handy tool. It consists of an upright frame 5 feet high, with a stout spindle running in one long bearing 12 inches from the ground. At one end of this spindle are fixed the fast and loose pulleys for driving, and at the other end the emery-band driving pulley, 2 feet or more in diameter, and flanged, of a width corresponding to the width of the largest emery band it may be desired to use. Guide pulleys to hold the band up to its work are provided on the side of the machine, and an adjustable flanged pulley for tightening the band at the top of the frame. The band consists of an endless tape prepared exactly in the same way as emery cloth. It is made in various widths. The driving pulley is generally urged so that the emery band has a surface speed of 3,000 feet per minute. Implements of irregular forms can be readily polished on this machine, and the band can be worked either wet or dry. Emery-wheel saw sharpeners are now familiar objects in

most saw mills, and their economy over the old process of sharpening by hand is obvious. In conclusion, it may be well to mention that, in order to ensure success in the use of emery wheels, plenty of power must be provided. No experiments, it is believed, have been made with the object of ascertaining the exact power required to drive any particular size or class of emery wheel; but it may be assumed that a 14-inch emery wheel will take as much power to drive it properly as a large lathe. Small as is the use of emery wheels at the present time, it will not be rash to predict that in a few years every engineer's shop in this country will be well supplied with emery-wheel machinery.

DRAINAGE UNDER DWELLINGS.

By S. FLINT CLARKSON.

From "The Builder."

However desirable it may be to avoid drains under dwellings altogether, back drainage is impossible very frequently for terrace houses—those houses put close together, which would always line the streets in the central portions of our towns. Anything which was desirable for other drains in less important situations might be considered absolutely necessary for those under dwellings, which should, of course, be as near perfection as possible.

1. *What to avoid.*—By pointing out briefly the bad qualities of brick drains, such as used to carry away the refuse matter from dwellings, what are good qualities in drains generally may be perceived without an effort. New brick drains are rarely constructed now-a-days, but plenty still exist under and around about old houses, so that they are not as yet mere matters of antiquarian interest.

In brick drains (and in drains of rubble stone equally) the materials were porous, absorbing liquid foulness, and giving it out in foul air when stirred, half dry, or dry. The bottoms were too frequently of bricks laid flat in mortar; the bricks grew loose, and the bed of the channel became a row of little cess-pits. In true barrel drains the round bottom was usually covered with cement, but it was applied with difficulty, and frequently not very smooth. With any slight disturbances the coating cracked, parts peeled off without anybody knowing where. Renewal was out of the question. There were thus always little pools above the porous bricks. Rats worked their way between flat covers and side walls, or enlarged any crack in a barrel. The bad air in the drain found its way into the building, and the rats, too. With bricks, barrels were not made less than 9in. diameter, which we know is too large for an ordinary house drain. Little streams of water turned through large flat-bottomed drains were shallow and slow; and in 9-in. barrels, with rough insides, there was but little improvement. The solid matter was left behind by the liquids; flushing, applied with the most extreme rigor, could not cleanse such drains. They were (1) of porous materials; (2) not smooth inside; (3) with joints too frequent, and soon becoming imperfect; (4) too large; (5) difficult to cleanse.

2. *Stoneware drains.*—All the defects noted above may be avoided if good stoneware pipes are used as they should be. They are manufactured in many places in the United Kingdom, and are not expensive, not nearly so costly as brick drains cemented inside would be. Well-burnt, hard, glazed stoneware pipes absorb no moisture; the vitrified glaze renders them as non-porous (1) as an old-fashioned brown drinking-mug; they do not corrode; they are quite smooth inside (2); once well cleansed the surface is what it was at first.

The fewer the joints the more perfect the drain. If one could be put down all in one piece we should do well, but nature has apparently not arranged for this. In the stoneware drains joints occur at every two feet, and if properly made they are very lasting (3). [These numbers are those of the defects in the

brick drains noted above; the contrast is thus pointed out, and the way in which a defect is overcome.] The length of 2 ft. is convenient for making, firing, conveying and handling; a length of 4-in. pipe weighs about 15 lbs., and a length of 6-in. about 26 lbs. In each batch of pipes there are failures which must be cast aside; they should never be sent out from the works. They may be of insufficient thickness, rough on their surfaces, too brittle, fired too much or too little, not cylindrical, or otherwise defective in form. The pipes are made thicker as the diameter is increased; a 4-in. pipe is $\frac{3}{8}$ in. or $\frac{1}{2}$ in. thick, a 6-in. $\frac{5}{8}$ in., a 12-in. 1 in. If too thin or brittle, the broken pipes will saturate the soil around them with foul matter; if rough on the surface obstructions will occur; in either case the drain will be blocked up. If they are not truly cylindrical in form (or not truly oval in the case of oval pipes), one pipe will stand above another at the joint and stop the flow. An ordinary pipe is constructed with a projecting rim or socket at one end—a faucet into which the plain end of the next pipe fits as a spigot. The inside of the faucet and the outside of the spigot have parallel grooves to give a key to the material introduced to form the joint.

The lowest pipe is laid first with the socket at the highest end. The plain end of the next pipe is placed in that socket, and the space between it and the socket is filled in with a mixture of cement and sand. Clay should not be used for drains under dwellings; there the joints should be as air and watertight and as indestructible as possible. Before the cement has had time to harden, the interior of the pipe is wiped out very carefully. *If this is not thoroughly done, a ridge, or small lumps of cement, will stick up at the joint.* Long hairs, threads, pieces of cloth or cotton stuff will attach themselves to such projections, soil will then cling, and a stoppage be managed sooner or later. To guard against such ridges or knots joints have been treated somewhat as in iron water mains, that is to say, strands of gaskin have been put around the upper pipe, so as to make it fit tightly in the socket, and then cement packing, put to fill up the rest of the socket, cannot reach the interiors of the pipes. Some lodgment results, however, and consequent imperfect cleansing, if the whole space between the two pipes is not solidly filled up with something as hard, or nearly as hard, as the pipes themselves.

3. *Some defects in stoneware drains.*—When pipes are ordered hurriedly and arrive too late, there is sometimes a wish to use those which have come, and not to wait further for the special pipes which ought to have been ordered before. When the changes cannot be made at the junctions, pipes of one diameter should always be joined to pipes of another diameter by diminishing pipes, and in no other way. Patched junctions are painful shows of inefficiency; obstruction comes sooner or later when the filling-up breaks down into the pipe. Right-angled junctions cause trouble; a branch should discharge through a junction at an angle approaching the line of flow of the drain which is entered. When bends are required, but have not been supplied, straight pipes will be used with apologies, "so as to get the work done," unless there is interference. If the curve is of short radius, the spigot ends will actually leave the sockets on their outer sides. Speaking generally, very bad stoneware drains will be of porous pipes, rough on their insides, broken and pieced with cement; some joints gaping, others leaking; some badly made with bad cement, some with projections of the cement inside, not sealed over, laid to curved and irregular lines, with right-angled junctions; the curves made of straight pipes, without diminishing pieces at change of size, and occasionally with larger pipes inserted in the run of smaller ones; without inspection chambers; put on new-made or yielding ground; parts running up hill, and the rest laid to flat and irregular gradients.

4. *Iron pipes and subways.*—Some architects, in certain parts of their best work, use iron pipes with yarn and lead joints, similar to those in water mains, in preference to any stoneware drains. In Paris they are always used, not buried in the ground but exposed to view. In America they are common, and compulsory in some places for drains under dwellings. They are enameled inside, or treated by the Bower-Barff (Rustless Iron) process. Mr. John J. Stevenson, the architect of the new mansions at

Kensington Court, has taken great pains there, and used all the most modern sanitary appliances. He has kindly lent me a drawing showing the system pursued. Heavy cast-iron pipes, 5 in. diameter, are laid in perfectly straight lines under the houses. They are lined with Dr. Angus Smith's composition, a preparation of tar, which gives a smooth and apparently indestructible surface. Joints occur at every six feet, and are thus one-third of the number in a stoneware drain; there are no difficulties with defective cement or the careless use of it. Being much more costly than stoneware pipes, the iron pipes are only used under the houses.

Similar iron pipes were put by Mr. E. C. Robbins on wall brackets in a subway —a kind of sub-basement—in the Museum of Building Appliances, in Maddox Street, Regent Street.

5. *Lines and levels.*—Long straight lines are always preferable. It is more easy to get the levels right and to see that they are so; there are no checks to the flow, which is a very important point with water-borne solid matter; they can be more readily tested at first, and from time to time, and more readily unstopped. At the junction of the straight lengths of the pipe drains, and at any bends, small inspection chambers are put; at the bottom of these a length of half-pipe forms the channel. When the cover is off the character of the flow of the drain is seen at once.

Having determined the lines which the drains are to follow, it is then necessary to settle the inclinations at which they shall be laid, in order that they may convey all effete matter quickly to the sewers, and be self-cleansing. Of course, if there was too much fall, and the slightest check, the solids would remain and the water run away. But too much fall is the rarest thing; not being able to get enough is what we are wont to grumble about. The fall is strictly limited by the depth of the sewer below the lowest floor, and the necessity of keeping the drain well under the floor at the upper end; 2 ft. under the finished floor is considered desirable though we have sometimes to make ourselves contented with less. The least fall approved for 6-in. drains is 1 in 40, that is, 3 in. fall in each 10 ft. of horizontal distance. More is valued if it can be managed, certainly 4-in. drains should have more. It is desirable to have a flow of at least 150 ft. per minute with a shallow stream of water. When drains are laid to flat gradients some special means of flushing them must be used daily.

If the pipes are laid upon yielding ground they will not keep level; some will tip one way and some another, the joints will snap, and sometimes the pipes also, resulting in hills and dales, leaking joints and stoppages. A bed of cement concrete, carefully leveled on the top to the proper fall—a bed of artificial rock, in fact—laid along the whole length will give the pipes a fair chance. In this concrete grooves will be made to receive the lower parts of the pipe sockets, and the whole of the length of each pipe will then rest on an immovable bed.

Refilling the trench must be managed without disturbing the pipes. The hollows under them being very carefully filled up with concrete, it must also be put at the side of the pipes, with a thickness of 6 in. on each side, and then 6 in. over the top. Such a covering of cement concrete is usually stipulated for in by-laws for drains under dwellings, sealing up the pipes altogether as an additional precaution against evil results from defective jointing. It also serves to protect the pipes from displacement by impact on the surfaces above them.

6. *Disconnection from sewer; ventilation; connection with sewer.*—After the house drain has left the house, and before it reaches the sewer, a break is made, and the drain runs past an open space. On the side of this air space, next the sewer, is a water-trap with a good seal, intended to prevent any bad air in the sewer from reaching the air space. If, however, this trap is neglected, or pressed upon a good deal from the sewer, tainted air will not enter the house, but will find its way out of the air space. From the air space fresh air enters the drains under the house, and a current is kept constantly moving through them by arranging ventilating pipes at the higher ends, which shall run up to the top of the building.

Some disconnecting traps are large shaped pieces of stoneware, which shut off the sewer at one end, and receive the house drains at the other. A pipe car-

ried up at the house end supplies the fresh air above the trap, when a grating at the surface of the pavement is objected to. With other traps the construction of a manhole is contemplated. This is a little chamber built up under the pavement of an area, through which the drainage is carried in half pipes of enameled ware. The trap is a siphon or U trap put on the side of the manhole next the sewer. A grating at the surface is sometimes put when there is plenty of space; more usually a flue is constructed and filled in with a ventilator having small mica valves, which rise to admit air into the flue, but refuse to let the air come out. In time of storm there might be a set in the wrong direction—the long upright pipe at the back of the building might carry a rush of air downwards, and it would find vent at the induct and cause annoyance. Protected by these mica valves, the flue is unsuspected, and a moment of rest allows the pent-up air to go upwards according to its wont. The manhole makes inspection of the drains easy; an air-tight iron cover is often put over it.

The ventilating pipes, at the upper ends of the house drains, are of lead, or of galvanized cast iron, well caulked at the joints, and all 4 in. in diameter, or as large as the branches they start from. The soil pipe serving the water-closet is usually extended upwards; being joined at its foot to the house drains without any trap, a current of air passes steadily through drains and pipes. Long branches must have special ventilating pipes; short ones will be cleared of air by the discharges, and supplied with freshened air from the main drain. These upcast exhaust pipes must not finish near windows or cisterns, nor be stopped at the eaves, so that they discharge under the open joints of slating; nor must they stop just above the tops of chimney flues, nor be carried into the flues themselves. If they are, bad air will reach the insides of rooms. Wires, or a perforated finial, or an approved cowl, must be put to keep out birds.

The drain should be connected with the sewer in the upper half, above the line of flow, at the haunch just above the springing. The custom at one time was to put the mouths of the house drains below the water level in the sewers, but this is given up now; the intention was to prevent sewer air entering the drains. Connections must join the sewers obliquely in the direction of the line of flow of the sewer. The pipe-sewer junction blocks invented by Mr. Cockrill are a considerable improvement. Oblique junction blocks and bends are used for brick sewers. Flap-traps are railed at, and still used. The hinged valve allows a passage out from the house drain, but not into it; the flap closes by its own weight when the flow has passed through.

7. *Inspection, flushing and cleaning.*—Other connections with house drains for sinks, baths, rain-water pipes, &c., the traps to them, and the ventilation of pipes and traps, form a branch of our subject not forgotten, but very extensive. The construction, maintenance, cleansing, and the efficient ventilation of sewers might seem another branch. Everybody is interested in it, architects specially so. It is well, however, for everybody to have his own province and do the best he can in it; and architects are content with a province which extends, in large towns, as far as the walls of the sewers, but not beyond.

When the drains are completed, disconnected, connected, and ventilated, they must be examined keenly before they are used, so that if by chance there are defects, they may be remedied. If the lower end of the house drain is plugged, and the pipes were filled with water and left for a few hours, and the level of the water in the testing-bend has not sunk, it has been proved that pipes and joints are sound, that there are no vents for bad air, or cracks through which moisture will run away. The levels of straight drains can be tested by actual measurement, and the effectiveness of the gradient proved by floating down something in a good flush, and noting the time. At cast-iron terminals, with air-tight brass plugs placed in a back area at the upper end of a drain, various tests for soundness and level can easily be applied. With drains in use water mixed with lime is poured in at the end. By the amount and character of the discoloration of the effluent water, before and after flushing, the condition of the insides of the pipes will be judged.

The beautiful arrangement shown by Mr. Hawksley (470, Class 22) for testing house drains and soil pipes with a plumber's force pump and gas-pressure gauges, shows when there is any leakage, and localizes the leakage, too. The traps act as plugs; the ventilating pipes and the end of the house drain next the disconnecting trap must be thoroughly plugged up. The smoke test calls attention to important defects; little holes may, it is true, be plugged up by some chance at the moment when the test is applied. Straw burned in the drain may send smoke all along it, or smoke may be generated in a vessel and forced in by a machine. These appeal mainly to the sight. The peppermint test—a favorite one, on account of the ease with which it is applied—appeals to the sense of smell, as does sulphur burned in a shovel at the mouth of the disconnection chamber. Ether, oil of mint, and other strong smells have been suggested. The difficulty in actual life is in getting anybody to look for defects periodically.

SPEED ON CANALS.

By FRANCIS ROUBILIAC CONDER, M. Inst. C. E.

From Proceedings of the Institution of Civil Engineers.

II.

Mr. J. Evelyn Williams stated that to any one engaged like himself on river and canal engineering, the paper was one of much interest. Comparing the speed on canals with that on the open sea, it was obvious that in a deep open seaway the void formed by the vessel freely filled up again by the water closing in under the stern.

In a contracted shallow channel the movement of the vessel set in motion the entire sectional capacity of the canal, and the void at the stern was filled, in a great measure, by the water flowing backwards through the narrow passage left between the vessel and the sides of the canal; therefore the fulcrum or thrust of the propeller was diminished, and a considerable amount of power was expended without useful effect. The author stated that with a speed of from 8 to 9 miles per hour on the Clyde, a wave was caused 8 or 9 feet in height. Now a wave 8 or 9 feet in height would represent a speed of 14 knots per hour, and require about 24 H.P. per square foot; but as the ends of a vessel were beveled off, this theoretic wave would be very much reduced in height, and the power expended in propulsion would be only a fraction of that due to the wave stated. In short, since the resistance of water to lateral displacement, varied as the square of the velocity with which it was displaced, it followed that the resistance would vary as the square of the sines of the angles formed by the bow and stern with the keel. Suppose a modern fine-lined vessel with a speed of 16 knots per hour, the head wave due to that speed would be about 11 feet; but as the bow and stern had an angle of 15° and 20° respectively with the keel, there was no such wave visible due to the resistance of the vessel. With this form of vessel, it would be found that the resistance fell off to about one-sixth that due to the theoretic head of 11 feet.

Putting R = Resistance.
v = Velocity in feet per second.
W = Weight of a cubic foot of water.
a = Midship section in square feet,

then $R = a \,.\, w\frac{v^2}{2g}$, and putting $W = 2g$, or $64\frac{1}{3}$ $R = a \,.\, v^2$. Now if the bow was beveled off to an angle θ with the keel, and the stern to an angle $0'$, then R became

$$R = a\,v^2\,(\sin.^2\theta + \sin.^2 0'),$$

and as power was the product of resistance and speed the H.P. would be

$$\text{H.P.} = \frac{a\,v^3\,(\sin.^2\theta + \sin.^2 0')\,60}{33{,}000} = \frac{a\,v^3\,(\sin.^2\theta + \sin.^2 0')}{550}$$

For illustration take a run of the R.M.S. "Germanic;" speed 18 miles per hour =26.4 feet per second; midship section =944 square feet; angle of bow with keel=15°; angle of stern=20°; then

$$\text{H.P.} = \frac{944 \times 26.4^3 \, (0.0670 + 0.1169)}{550}$$

$$= 5{,}808.$$

The actual indicated H.P. was 5,434.

With reference to the cross-section to adopt for a canal, the semi-elliptical section was no doubt a plausible one in theory; but where the strata were of a yielding character, it was with its curved profile, both with regard to cost and facility of execution, practically an impossible one. The author stated that the cost of the Suez Canal, as constructed, was £143,585 per mile, whereas the cost of the walled semi-elliptical section of the same area would be only £80,682 per mile. The Witham Outfall cut, 3 miles long, and drawing to completion under his supervision, was about the same depth as the Suez Canal, but of much greater sectional area, and with side slopes of 4 to 1, and would cost under £50,000 per mile. He should like the author to state the price at which he calculated the cost of the excavations; and also the amount and price of the walling in the semi-elliptical section, as he could not see how the difference in the total cost could be so great as mentioned.

Mr. Robert Gordon observed that he had never had any opportunity of experimenting directly on matters connected with this branch of hydraulics; but his work for many years had given numerous occasions for observations on several points of interest relating to it. He had repeatedly journeyed for weeks at a time in river steamers of from 200 to 600 tons, and in steam launches, at all stages of water, both on a large river and on small natural channels, as well as on artificial canals; and the phenomena accompanying the retardation of vessels in shoal water and restricted channels had been impresively forced upon him. On one canal in particular, about 7 miles long and about 40 feet broad, near Rangoon, he had passed with barely sufficient water to float the launch, with the tide rising in the same direction from behind the launch till the water became 6 to 8 feet deep. At first not more than 1 mile to 2 miles per hour could be got with full speed, and with the greater depth of water only 5 miles were attained. He had also gone through when the water was 10 feet deep, steering himself, and observing closely the retardation and wave formation as the vessel passed at extreme full speed. The launch had some 50 square feet of immersed cross-section, and could make over 10 miles an hour in deep water; but in the canal, which then had about 500 square feet of cross-section, she could not make quite 7 miles per hour. On applying the author's formula to these data he found the results given somewhat at variance with the facts. The actual retardation of the boat in the canal thus varied from 9 to 5 and 3 miles per hour, while the back current, which the author assumed to be the sole cause of the retardation, was, by his formula, only 0.77 mile per hour in the last case. In actual practice no such general back current was observable in the channel, but a strong commotion was set up in shallow water immediately near the hull, which could be best studied in somewhat analogous conditions when a vessel was anchored in a strong current with less than 3 feet depth of water under her. It would then be seen that strong eddies rose up near the stern, and if the bed of the stream was easily acted on by the water, a considerable excavation of the material just below the vessel occurred. Doubtless the same kind of eddying took place under a vessel in rapid motion in shallow water, and it was disturbance of this kind that interfered with the steering. But in any case it was found that the retardation and deficient steerage power were much more strikingly developed in shoal water with only a few feet between the bottom of the vessel and the bed of the canal, whatever the breadth of the stream might be, than in a restricted narrower section of greater depth. This he had frequently had occasion to observe in river-traveling, the shoaling of the water being indicated by a loss of speed, a commotion in the water, with large waves forming on its surface, and defective steering power. He would ascribe the numerous accidents and stoppages on the Suez Canal entirely to this loss of steering power in the large ocean steamships, with their small rudders, and only a few feet of water intervening between their keels and the bed of the canal;

and he believed that more would be done to facilitate the traffic across the Isthmus of Suez by deepening the canal 6 feet than by widening it 60 feet, as vessels could pass with a higher speed and more security in steering with the increased depth than with greater width.

The form of the canal was of much less importance than the depth. The author referred to Mr. Bazin as saying that the form of the channel must be regarded; but what Mr. Bazin did say was, that the form of a channel did not appear to exercise any importance on the flow, although a completely curvilinear canal might discharge nearly one-tenth more than a polygonal one; yet, as such regular curves were rarely found in practice, the form of section was not taken into account. The author's elliptical section had the disadvantage of offering rather steep sides, which would certainly fall in in such soft material as the Suez Canal traversed, and the nature of the ground must generally determine the shape.

If it was desired to study the theory of the resistances to vessels passing through restricted and shallow channels, the labors of Mr. Scott Russell, as well as those of Bazin and of Froude, should be taken into account, as no one has done more than he had to place the matter on a scientific basis. Mr. Froude had contributed most valuable results to the knowledge of the resistances to vessels in the open sea, in memoirs, where he showed that this resistance depended on two forces, the one which might be called skin-friction forming the whole resistance at low speed; the other, which only came into existence when the speed was increased, might be called the "wave-making resistance." This latter arose from the continuous formation of two kinds of waves as the vessel passed through the water; the one kind consisting of the diverging waves formed at the bow and running off obliquely, but retaining their original size for a great distance, while they dissociated themselves from the vessel and opposed no further resistance than the loss of power due to their original formation. The other kind of waves occurred in series and ran transversely to the course of the ship; the first wave being the greatest had its origin at the bow, and was followed by other waves parallel to it, and which might strike the rear of the ship, while a terminal wave appeared near the stern of the ship restoring the equilibrium disturbed on the formation of the bow waves. Mr. Froude found by experiments on a series of models of ships, all built on the same lines and same cross-section, but with different lengths of parallel-sided middle body, that the resistance at high speed was very much increased in dragging the models through the water, if the hollow, or trough of one of these transverse waves came a short distance in front of the stern-post, and it was much lessened if the crest of the wave struck the counter in the same place. These conclusions of Mr. Froude would help much in understanding the results of some of Mr. Scott Russell's experiments on canals. He was the first to discover the existence of what he termed the primary or carrier wave, a wave of translation, as distinguished from the ordinary wave of undulation or oscillation. He found that in a channel 20 feet long, 1 foot broad, and 1 inch to 7 inches deep, he could by the sudden protrusion of a solid mass, or addition of water, cause a wave to travel along and above the surface of the water at a velocity which equaled the square root of the total height of the crest of the wave above the bottom of the channel. This wave caused an actual transference forward in its own direction of every particle of water in the trough or channel. Mr. Bazin repeated these experiments in a channel more than 20 feet wide and about 8 feet deep, and verified Mr. Scott Russell's results, which he declared to be exact for still water, but only approximate where a current existed. Mr. Scott Russell some years afterwards made further experiments on a canal near Preston, about 30 miles long, in order to study the effects of wave-formation on the resistance to the passage of vessels on canals. He found that by keeping the whole of the boat traffic on the canal in one direction for a day he caused an actual transference of the water in the canal from one end to the other to such an extent, that it was 18 inches deeper than the normal at the one end, and 18 inches shallower at the other. This was entirely due to the formation of the primary or carrier waves, which took their rise at the bow of each vessel, and, after

accumulating to a certain size, shot off at a velocity solely due to the depth of water in the canal, and had no relation to the vessel's speed. In 1 foot depth the carrier waves ran at 4 miles an hour; in 5 feet, 8 miles; in 15 feet, 15 miles; and in 26 feet, 20 miles an hour. A considerable amount of energy was expended in this wave-formation, which corresponded to the diverging waves of Mr. Froude in the open sea.

But another class of waves still more important in their relation to the resistance to vessels in canals, was the secondary class of waves, which appeared to be undulatory or oscillating, and like Mr. Froude's transverse waves in open water, constantly accompanied the vessel in her movements. Mr. Russell had described some of the phenomena of these waves, and had given an account of the form and mode of formation of those he observed. The bow-wave was heaped up in front of the vessel; a negative wave or trough accompanied the body of the vessel, and was followed by another large crest of a wave behind the stern, which showed a tendency to break, and did all or most of the damage recorded of destroyed banks of canals. He had constantly watched these waves form in a marked manner in shallow water, irrespective of the fact whether it was in a narrow canal or in the broad river; and it was to the attendant conditions and results that he would ascribe the great retardation observable in passing from deep to shoal water. Possibly the fact that the negative wave, or trough, acquired such prominence in shallow water, near the after part of the body, might account for a great portion of the retardation. It was well known tbat stern-wheelers could not work in very shoal water, as their after part often sank so low as to cause them to touch the bottom. Probably the eddying water under the keel and around the stern explained some of the increased resistance; but it was clear to those who studied the subject in the writings of the eminent men who had already worked at it, that great prominence must be given to the whole of the allied phenomena of wave and eddy formation, particularly in shallow waters; and that both the whole depth of the water and the distance between the keel of the vessel and the bottom of the channel below it must enter as factors in any formula professing to express these phenomena mathematically.

Mr. J. Herbert Latham wished to add one remark to what had been said about the depth of the canal. The bows of the boat when they struck the water drove it in different directions, and it had to escape. This was seen most clearly where a flat board struck the water perpendicularly; the water was driven round the sides and under the bottom. The same thing happened when the striking surface was much inclined, as in the bows of a sharp canal boat. The force and the velocities generated were very much reduced by the water striking at a great inclination. The effect in either case was that the water that escaped upwards created a wave at the top of the surface, which increased to such a height that its weight operated to check the rise of water, and to promote the escape of water underneath the bottom. The progress of the boat in the canal was much facilitated if it was easy for the water to escape underneath the bottom instead of having to pass the whole length of the bows, and so necessitating more head in the wave in order to drive the water at greater velocity. In order to facilitate the escape of the water underneath the bow, and so to allow the wave to be as small as possible, a broad and shallow boat was necessary having underneath a clear waterway in most cases, if it was a sharp bow, larger than would suffice for the sides. The water should be moved as little as possible. As the water was moved along the sides or underneath, it should go on lines parallel to the sides of the canal until it closed again at the rear; and if there was a bulging bottom it was possible that water which escaped underneath the forward part might have to be driven aside amidships, and to be sucked in again at the rear, and so a motion created in the water which not only absorbed power, but interfered with the flow of the water. In some American canal-boats the horizontal section through the broadest part of the boat showed the inclination of the bows 4 to 1. His notion was that such sharp bows were best; and underneath those long sloping bows the water could escape under the bottom. At the rear where the boat began to contract, and before the velocity

of the water was checked, the depth of water would be reduced; in fact a depression would occur at the stern, which saved so much elevation at the bows, and he did not consider that was objectionable; the difference of level between the wave at the head and the depression at the stern representing the head which drove the water past the boat. The object in drawing in the stern should be to allow the water flowing rearward along the sides and under the bottom of boat to take up a position of rest in the canal in rear of the boat with the least commotion possible. In one of the cases quoted by the author, the area of cross-section of canal water was four times that of the boat; that would involve an average backward velocity in the water, as it passed the boat, of about one-third the velocity of the boat; and this water should flow past the boat in behind the stern equably. He believed the best sort of boat was one that had a considerable breadth of stern, and a paddle-wheel in the rear. In short, what he suggested was that the sides of the bow should be fine, that the bilge and lower angle of the bow should be rounded for the escape of the water, and that the stern should be such as to be something like a section of an overflow near the *vena contracta* (an adaptation of which was seen in the interior of a nozzle of a fire-engine), but very much elongated to suit the circumstances. It should be such that the water flowing in from the sides, and the water rising from below, to form the wave that followed the ship would have its velocity checked equally. With regard to leaving waterway under the bottom of a vessel, he would instance the flat boats used on the Godavery. They were square bowed, the whole of the water was driven downwards, the bottom was fiat, and they would go 8 miles an hour. If they were crossing a sand-bank the water would suddenly pile up at the bow, being unable to get underneath. There still was water to float in, but it had not been able to escape underneath. With those boats the whole of the water that was displaced had to be sent underneath them. In the Suez Canal the ships must be taken as they were found. They were not built for canal service. but still there was no question that they should have such a depth underneath them, that any water would not have to be driven aside at a high velocity when the bulging part of the vessel passed. If that was done they would derive the full benefit from any widening of the canal, and in his opinion deepening the canal was of much more importance to speed.

Mr. Alfred Giles, M. P., said, when he heard of a bow wave of 11 feet on a canal, and of a wave of 8 or 9 feet on the Clyde being forced up by the speed of a vessel, he was disposed to say that that was quite contrary to his experience. He had had considerable experience in observing the waves thrown up by vessels at high speeds, alluding more particularly to the trial trips of steam vessels, and from his observation he doubted whether a wave as described could be produced by any vessel of ordinary and proper form. He had crossed the North Sea in very rough weather, and he had had the opportunity of measuring the highest wave he could find, and that, he thought, was 22 or 23 feet. He crossed from Calais only the other day, after the late storm, and he did his best to measure the height of the waves from the trough to the crest, and the extreme wave was not more than 9 feet. Very few people knew unless they had tried to measure it what a wave of 9 feet meant, and he doubted whether it was possible to raise a wave of 11 feet by the ordinary passage of a boat in a canal Unless canals were made wider than would be necessary for the ordinary transit of boats, the speed at which boats of an improper form should be allowed to traverse them ought to be regulated. He believed that a boat could be designed to go with the greatest speed through a canal scarcely causing any wave; but if a tub like an old wooden collier were put in the canal, and driven 6 miles an hour, a wave would rise that would do very much damage to the banks. It was not a question of tubs or theoretical vessels; but of vessels of practical and useful shape, such as would be adapted to go through the Suez, Panama, or any other canal, and he thought that a vessel of any ordinary form going through an ordinary canal at 6 or 7 miles an hour need not create any wave which would be damaging to the banks. Of course the greater the speed the greater the wave that would be formed; but taking the ordi-

nary speed at which a vessel would go through a narrow channel, it depended very much upon the form of the ship whether the banks of a canal would suffer damage.

Mr. J. D'A. Samuda considered this one of the most important and interesting subjects that could possibly be brought before any Institution. He thought if the discussion were transferred to the great legislative chamber, the Suez Canal question would be dealt with in a very different manner from that which probably it might be there treated from an imperfect knowledge of the issues involved. In the main, the points which had been urged in the paper appeared to him to be correct. He had no experience of canal work, but he had an experience quite equal to the ordinary amount with reference to the passage of vessels through water, and he must say that there were circumstances in this inland sea which, having once been formed, had become such an important factor not only in the commercial but in the political necessities of the country, as to render it of the utmost importance for the Institution to afford such assistance as might enable that canal to be made useful for the purposes for which it was originally designed. It was perfectly clear that however good the design might have been originally, and however well intentioned the construction of the canal for the use which it was expected would be made of it, it was utterly unsuitable to the traffic which was now passing through it, and would become considerably more so with the increased quantity that every year brought upon it. The owners of the canal had dealt with the matter of its improvement in conjunction with the shipowners of this country from a point of view with which no one could find fault—that was to say from the shipowners' point of view. The shipowners no doubt had a great desire to get the freights reduced, and they had succeeded in showing Sir Ferdinand de Lesseps the advantage that would result by reducing the freights. He, on the other hand, had been prepared to accept their view, probably with the idea of condoning that which he had done, and getting further license to do that which he might want to do in the future. What the public in this country were most interested with was that the canal should be able to accommodate what they required, and considering that India and Australia were becoming our main reliance for the supply of food, especially corn and meat, and with the knowledge that in England there never was more than four months' food at their disposal, and that without every inland sea and ocean route being open to them to bring food they would in many cases be absolutely starved, it was of the utmost importance that the canal should become a real, efficient, and useful thing. It never could be made useful and efficient if, having admitted the total inability of the canal to deal with the traffic passing on it, another canal should be cut and the traffic divided, one canal serving the traffic passing one way, and the other canal the traffic passing in the opposite direction. Such a course seemed to him to be quite out of the question; the author put the matter very clearly in that respect, for he showed distinctly the amount of retardation that vessels were obliged to submit to in passing through the canal from the resistance which they met with, from the shallowness and narrowness. However magnificent the second canal might be in one direction, there would be a limit in the opposite direction owing to the existing canal, even though it was made still deeper than at present. The Institution might therefore most advantageously direct attention to the inconvenience which the public were at present obliged to submit to. What was a speed of 5 miles an hour between two hemispheres? Here there were vessels going regularly at 12 to 14 knots speed reducing their speed to 5 knots, constantly coming to grief, constantly being blocked. Some of his own family had passed through the canal more than once, and on every occasion they had been stopped two or three days by other vessels having got aground, or in some way or other becoming entangled. He did not wish to make this a discussion with reference to the course that the canal should take. There were others present who had already pointed out the enormous advantage which might result from doing away with this little ditch, and substituting for it a sufficiently wide, large, and deep channel for dealing with the traffic that had to pass through it,

and it would be clearly shown that trebling the width would in all ways greatly increase the advantage of passing through, because the resistance would be decreased enormously as the width and depth increased. He constantly had vessels on the Thames, and whenever they had passed over any shoal, something like that which was found in proceeding over Barking Shelf, it seemed as though the vessel had been going at an increased speed, whereas the reverse had taken place. The vessel had been held back seriously by its nearness to the bed of the river, whilst the paddle-wheels had revolved very much more freely by reason of the extra amount of slip which had taken place. He might observe that the whole of Mr. Latham's remarks seemed to be based upon the supposition, that water might be driven in one of two directions; either round the side of the ship, or under the bottom of the ship. It appeared to him utterly impossible that any water could be driven underneath the bottom of the ship. Unless a way could be found by which to compress water, he should like to know how a single particle of water could be driven except round the side of the ship? Therefore the width of the canal was of material importance, so as to afford space to get rid of that water which must be pushed out of the way to enable the ship to go through, and must fall in again to enable the space to be filled up. To pass water underneath the bottom of the vessel, either the water must be compressed, or the ship lifted out of the water, and thus caused to travel supported on a less quantity of water than was due to her displacement, either of which processes were perfectly impossible.

Sir Robert Rawlinson, C. B., as an old canal engineer, might have something to say upon this subject, and as a preliminary he would wish to remark that formulas were very useful, but only as the alphabet, to lead to something beyond. He ventured to say that no single formula could be devised, which should be applicable in all cases to canal and river navigation. There were certain rules, however, which were unerring, as, for instance, the squares of the diameters of pipes, and their capacities; but there was not a single formula which was applicable to the flow of water through pipes of small and large diameters. Many had been promulgated which might be true of the pipes upon which the experiments were made, but they were not true when those diameters were increased. He had heard it suggested that the Suez Canal was to be deepened and widened. Several accounts had been given of the enormous cost of making it what it was, and some intimation was conveyed almost every week of the difficulty in getting vessels through that canal. The public in general might not be capable of understanding how these difficulties arose, and that enormous cost had arisen. The canal, where the difficulties now arose, had been dredged through sand; on the section before the meeting there was shown a level bottom and sloping sides, with shallow top margins for extra width of the water. That section had been objected to; but he had no doubt that the French engineers could give some very good reasons why they had adopted it. But what were the difficulties naturally? Being sand, there was a constant tendency for the excavated channel to close by the rising of the bottom. That bottom being sand took the nature of quicksand, and there was a tendency also of those sides, however flat they were laid, to slip, and so shoal the deeper water. A railway cutting might be taken as a dry canal, and the slopes were laid back according to the nature and character of the material through which the cutting was made. There were slopes at 1½ or at 2 to 1, but through the lias shales and some other formations, the sides slipped in. After intervals of years, those slopes had been a perpetual torment to the engineer. That state of things being so in dry cutting, what must be the state in wet sand cuttings similar to the Suez Canal? He imagined that Sir Ferdinand de Lesseps knew by experience pretty well that if he had to make a canal to give capacity for traffic, he should not attempt to widen that canal to twice its present width; for if he did, he would increase the difficulty of keeping it open fourfold. Sir R. Rawlinson would much rather know that Sir F. de Lesseps was going to content himself with a single line of canal to pass the traffic in one direction, and that he would cut a second canal, if one must be made, for a line of traf-

fic in the other direction, making the cross-sections small in order to reduce the enormous annual costs of dredging. With regard to the speed of boats on canals, canals as constructed in this country were made for slow speeds. When they were constructed the only form of traction was manual or animal power, and the speed was necessarily confined to some 1½ mile or 2 miles an hour. He did not think any one in the room had had more propositions put to him for bringing in new methods of traction upon canals than he had. He used to have a project about every three months to consider and report upon. The projectors, as projectors, did not appear to know that twice two only made four, and not by any possibility make any more. Many of them brought forward their schemes never having studied a canal, never having looked at the traffic going along it, but imagining, in their study or home, that they had hit upon some beautiful theory by which to get impossible speeds upon canals. Mr. Samuda had said that water did not pass under the bottom of a boat in motion. Sir. R. Rawlinson knew to the contrary, as that under some conditions was exactly what it did do, and he would mention why. Upon the Bridgewater Canal the highest speed perhaps ever got upon an inland navigation had to be 9 miles per hour, but this was got by horse-power. The boats were termed "swift boats." They were about 80 feet in length, 6 feet beam, and drew laden about 2 feet 6 inches of water. It was necessary to run those boats at 9 miles an hour, as they could not be run at any other speed, that was to say, they could not be run practically at any other speed than 9 miles an hour; because the wave raised at this speed must be kept about one-third under the bow. There would be a trough ahead and a wave behind; and scores and scores of miles had he steered a boat going at that rate. If the horses failed, the boat slackened, and the wave got away from her bow; the boat must then be stopped, and another wave generated. To show that some different action took place with the swift motion of that boat as compared with the slow traffic upon the canal, large quantities of silt or mud used to require removal every summer under the ordinary slow traffic, but when the swift boat had been established, the bottom was clean. Now, if there had not been a backward motion of the water underneath the boat when moving with that velocity he did not know how there came to be so clean a bottom as he found in the canal. With reference to modes of propulsion, one man, imitating atmospheric railway modes, projected a scheme of laying an iron pipe along the towing-path, filling it with water, having a piston, and towing the boats by running the water in front out down an embankment. That was taken up by the late Lord Ellesmere, and he remembered making a very elaborate report. He thought he did it mischievously, because he went into all the details, ending with the remark that one night's frost would seal it up. When Lord Ellesmere came to that paragraph he said: "Why did not you put that at the beginning?" Another proposition was to pile the canal on both sides and make an elevated railway, to put engine power on the top of this elevated railway, and to draw the ordinary boats, which were 15 feet wide, along at 12, 15, or 20 miles an hour. He went down to see the inventor in Liverpool, and found he was a pattern maker in one of the large foundries. He began to talk to him about the speed that he wished to attain upon the canal, and then said, "Do you know what would come of putting one of our 15-feet boats in motion at anything above 3 miles per hour—do you know what would take place?" The man said "No." "Well," I said, "I will tell you: it would sweep all the water before it out of the canal and ground itself on the bottom." I then said, "Are you aware of the nature of our traffic?" "No." "Do you know in what form the traffic passes along?" "No." "Have you ever seen the canal?" "No, I never have?" So the project was drawn without the man ever having seen the canal. Then methods were projected of towing by steam, but as paddles or screws created a counter-current at all bridge and stop-places, there was a suck and great scour on the banks, so that steam was not in his time adopted. He believed there were on some of the Yorkshire canals trains of boats taken along some 4 or 5 miles per hour by steam; but there was nothing of the kind introduced upon the Bridgewater

canal while he was there. There was small steamer on the old river called the "Jack Sharp," and as it went down in the narrow parts its speed might be from 2 to 3 miles, but when it got into the wider canal at Runcorn, it immediately attained with the same power something like 2 miles more, where it had wider and deeper water. He found that the swift boats put the whole body of water in the canal into motion, and the towing was harder upon the horses with a full canal than when the canal was low, showing that the suction that the boat had upon it in being hauled through the water was greater with the greater volume of water in the canal than when there was a lesser volume. Then, as regarded the wear and tear, it was simply enormous, both in horse-flesh, in towing-lines and in destruction of the canal. The swift-boat waves ran up against the sides, undercut the side walling, and ran over the towing path, so that it had to be protected some 2 feet high with sod-made banks to prevent the wash, and as the swift-boat traction was only put on to stave off railway competition, as soon as it was found that there was no use in attempting to do that, they were abandoned. One interesting experiment was made on a length of canal betwixt Preston and Lancaster (about 30 miles, without a lock), where the authorities thought they would have swift boats. They tried one of the swift boats from morning to night, but could not get the speed. At last they came to the conclusion that there was something in their canal that could not be overcome. Some one, however, suggested that they had better try the horses without the boat, and see if they could go 9 miles an hour when they had nothing to draw. They could not, so that it appeared that they had been working all day endeavoring to get a result which was utterly impossible. Then there had been suggestions for laying chains down on the bottom of the canal, and working from a surging-barrel, and he had been told that day of a plan for having a very heavy chain passing from front to stern, and driving from a wheel in the middle, letting that chain run down, forming a grip upon the bottom of the canal, but he did not know whether that was likely to be a working experiment or not. With regard to the Suez Canal, whatever might be done with duplicating it, it did not need any spirit of prophecy to say that, in its present form and at its existing section, it never would be worked at much less cost than it had been up to the present time, because so long as it was kept open, as a canal, so long must the managers pay the penalty by the same unceasing and costly dredging.

Mr. H. J. Marten said he was obliged to confess to a feeling of disappointment at the meagre amount of practical information contained in the paper. The author had furnished a list of no less than one hundred and seventy-nine English canals and navigations, in connection with which there were of course a great variety of sections, great variations in rises and falls to be encountered, various methods of haulage or propulsion, with various draughts and dead loads in vessels of various descriptions, hauled or propelled either singly or in train, all of which circumstances were more or less incidental to a complete consideration of the question of speed.

Out of this long list of canals and navigations, however, with all this rich variety of incident attaching to them, the author had only given the speed attained with horse-towage upon one English canal (the name of which was not mentioned), and the speed attained with steam-towage upon one other English canal, the Grand Junction; and upon two English river navigations, the Thames and Lee; and this information was unaccompanied by any particulars respecting the sections of the channel, draughts, loads, or descriptions of vessels employed. Instead of practical information upon these points, the author had submitted three or four sections to the Institution, which, except in circumstances of rare occurrence, were, for practical considerations, out of the question. These sections also were founded on a theory unsupported by any experimental test, and which, so far as theory was concerned, left everything an open question, totally unsolved by anything advanced in the paper. He could have wished that the author had spent some little time in conducting a few practical experiments, as they would have added value to the paper, and he was sure the records of them would have

been received by the members of the Institution with the respect and interest always accorded by them to original research. It would also have been of advantage, if in the table headed "Dimensions of Canal Locks" the author had given the draught or depth of each lock in addition to its length and breadth. This information was to a large extent available from public records, and should certainly form part of a table of dimensions.

With regard to the question of speed, Mr. Marten regretted to observe that in the table headed "Speed attained on Canals," the speed attained on English canals by horse-towage was set down as 27 miles a day only, which distance in the body of the paper was expanded to 30 miles a day, including stoppages. He thought that with a little more of that research, with a capacity for which the author was very properly credited, he would have found that the speed he had mentioned was very much less than that actually attained. Taking the case named by Mr. Lloyd—the journey between Birmingham and London—148 miles was performed in sixty hours, or at the rate of nearly sixty miles a day, although within the termini named there was no less than one hundred and fifty-five locks to be passed. This speed was double that stated by the author, assuming the day named by him to represent a day of twenty-four hours, and there was nothing in the paper to indicate any other period. As a further instance, the distance between Autherly Junction, on the Staffordshire and Worcestershire canal, and Ellesmere Port, 68 miles, was covered, including the passing of thirty three locks, in twenty-eight hours, or at the rate, from terminus to terminus, also of about 60 miles a day. Again, the time occupied in traversing the 25 miles along the Staffordshire and Worcestershire canal between Stourport and Autherly Junction, with an ordinary canal boat loaded with 30 tons and towed by one horse, was twelve and a-half hours. In this length the rise was 293 feet, and thirty-one locks had to be passed; and yet the speed between point and point was at the rate of nearly 50 miles a day. Under these circumstances he felt justified in saying that the statement made in the paper as to the rate of speed attained upon English canals was much below the actual fact. Referring next to the tabulated statement as to speed attained on navigations by steam-towage, he found the speed attained upon the Thames was stated to be at the rate of 5 miles an hour. No particulars were, however, given as to where or under what circumstances this speed was obtained, that was, whether with or against the stream, and whether with or without a cargo or hauling-tug. Hence the value of the information for future reference was limited. With a view to supply somewhat fuller information than that contained in the paper with reference to the speed attained on English inland navigations, he would instance the work done on the Severn. That river had been canalized between Stourport and Gloucester, a distance of 42 miles; upon this portion of the river the traffic was principally worked by steam-tugs, which hauled trains of from twelve to fourteen boats at a time. These boats consisted o "Trows," holding from 100 to 125 tons each, of "barges" holding from 80 to 90 tons each, and of ordinary canal-boats holding from 30 to 40 tons each. The ordinary cargo load in the train of vessels attached to the steam-tugs was between 700 and 800 tons. With a load such as this the distance down the river from Stourport to Gloucester was performed in seven hours. This, including the time occupied in passing the five locks intervening between these places, and all stoppages for taking on and throwing off boats, was at the rate of six miles an hour, or a traveling speed of between 140 and 150 miles a day. Coming up the river or against the stream with a similar load, the first stage of 30 miles' length between Gloucester and Worcester was accomplished in eight hours. This gave a traveling speed, including all stoppages, of 3¾ miles an hour. In this stage the lift in the locks, at ordinary summer level, amounted to 12 feet, or about 5 inches per mile. From Worcester to Stourport the distance was 12 miles, the time occupied four hours, and the traveling speed, including all stoppages, 3 miles an hour. The lock lift on this stage, at ordinary summer level, was 16 feet 9 inches, or about 17 inches per mile. The increased lock lift in this latter stage accounted to a cer-

tain extent for the smaller rate of speed attained upon it, as compared with that attained in the other stage.

Referring to the question of "Lockage retardation," Mr. Marten considered that this was under-estimated by the author. The lockage retardation upon the Wilts and Berks canal, which was the example given in the paper, was stated to be 0.434 minute per foot rise or fall. This, however, was only the retardation due to the mere act of raising or lowering the boat when lying in the lock-pit, and omitted from the calculation all those other factors of retardation which had to be practically taken into account, and which came under the head of "Lockage retardation," such as slowing in, getting under way again, waiting for turns, &c. The estimate in the paper was practically as misleading as an estimate of station retardation on a railway would be which included only the period during which a train was standing at a station between stopping and starting, and which excluded any allowance for slackening and getting up speed, and the other incidental retardations of a stoppage. In following this point a little closer he called attention to the case mentioned by Mr. Lloyd, in which, as compared with the speed attained in the pounds there was a retardation of nineteen hours in the journey between Birmingham and London. Of this period the time actually spent in the locks was estimated at five hours and six minutes; and that occupied in slowing, getting under way, waiting for turns, &c., was estimated at thirteen hours and fifty-four minutes. Taking the total rise and fall upon that canal between the points named at 1,108 feet, and the retardation as amounting to one thousand and forty minutes, the retardation was equal to nearly seven minutes per lock, or to 0.94 minute per foot rise and fall, or more than double the time represented in the paper. Again referring to the journey between Stourport and Autherly Junction on the Staffordshire and Worcestershire canal, the speed of an ordinary canal-boat loaded with 30 tons and towed by one horse, was about 3 miles per hour along the pounds. At this rate the distance, 25 miles, should be done in eight hours and twenty minutes. Owing, however, to the lockage retardation, the time actually occupied was twelve hours and thirty minutes, thus showing the lockage retardation to be four hours and ten minutes, equal to eight minutes per lock, or 0.85 minute per foot rise. A better example of the effect of lockage retardation was, however, to be found in that produced by the flight of twenty-one locks between Autherly Junction and the Birmingham canal. These locks lay within a distance from the top to the bottom lock of 1½ mile. The rise was 15.9 feet, or about 7 feet 7 inches per lock. The average time occupied in passing an ordinary canal-boat through these locks was two and three-quarter hours; and allowing half an hour for the horizontal distance gained, there remained two and a-quarter hours, or one hundred and thirty-five minutes as representing the "lockage retardation." This gave about six and a-half minutes per lock, and as before 0.85 minute retardation per foot rise. From the above examples it would be seen that the lockage retardation upon canals having a rise and fall of from 8 to 12 feet per mile amounted to about one-third of the traveling time. It would also be observed that "lockage retardation" upon any particular canal was due not only to the time actually spent in the lock pits, which would be equal to the total rise and fall multiplied by the time occupied in filling or emptying 1 foot of rise or fall in the locks of that canal, but also to the time occupied at each lock in slowing, getting under way again, waiting for turns, &c., multiplied by the number of locks to be passed; and the sum of these two factors would represent the total "lockage retardation." Mr. Marten stated that, for practical reasons, he did not anticipate much greater speeds than those already attained could be reasonably looked for in the future of inland navigation in this country. In his opinion improvements would have to be made in the direction of lessened "lockage retardation," and in carrying larger loads per boat where the prospects of future traffic were of such a character as to justify the outlay necessary for effecting such a "change of gauge."

Although he was unable to concur with several of the statements contained in the paper, he considered that the author deserved well of the institution in bringing the subject before it, and he trusted

that the ventilation which it had received during the discussion would be of permanent value.

Mr. J. B. Redman said the subject matter of the paper and the discussion thereon were of considerable interest, from two causes: first, the remarkable success of the Suez Canal, notwithstanding all its physical drawbacks; and secondly, the renewed attention which was being directed to the development and improvement of the inland navigations of Great Britain. With reference to the Suez Canal, he referred to a paper, published a few years back, by Captain Steele, the Secretary of the Mercantile Marine Board, who had described the canal as a practical navigator, and who would be able to tell what were the difficulties from a seaman's point of view of navigating the canal in its present condition. A mere inspection of the Admiralty chart would show how very confined the channel was for the vessels now navigating it. The entire length of the canal from sea to sea was 98 statute miles. It had twelve "gares," or passing places, about 6 miles apart on the nothern section, and from 3 to 4 miles apart on the southern. Ten of the "gares" were on the western side, and two on the eastern, which appeared to show that the western side was that which admitted most easily of, and afforded the greatest facility for, widening. But an inspection of the chart would also show that the widening could be carried out on some portions of the canal, but in the narrow parts of the canal it was clear that, to get double the width for vessels to pass each other, it would be necessary to have an entirely new bank on the outer side of one of the existing banks, and constructed before the intervening bank was dredged away, and for the navigation at the same time to be kept open. That, of course, would be a work of some considerable difficulty. Mr. Samuda had stated the disadvantages of duplicating the canal with a canal of similar dimensions, as compared with the existing canal widened, or a canal wide enough to admit of passing vessels on an entirely new route. It was clear that the great drawback to the existing line of canal arose from the frequent stoppages occurring from vessels grounding; and in a canal double the width, or the existing canal widened, it was evident that if a port regulation were adopted, and the vessels outward bound or homeward bound hugged the port side, in the event of an accident happening to a vessel, it would be confined to that vessel, and the navigation could be continued. Again, a canal double the width would admit of the water displaced by the vessel navigating its channel passing freely on either side; the wave raised in front of the vessel would be of less height, and the retardation would be consequently less. There was another point connected with the present route, with regard to the question of widening or an entirely new canal. The soundings in portions of the canal were 27 and 28 feet, but in a large number of places they were only 26 feet and 25 feet; 25 feet was the ruling depth. That applied to the two lakes, the Great Bitter Lake and the Little Bitter Lake. The Great Lake was fully 25 feet deep; but the smaller lake was only half the depth, with a submarine 10-feet channel dredged for the passage of vessels. As to the author's statement that the subject of retardation to the passage of vessels through narrow channels had not been considered until of recent years, Mr. Taunton had referred to a large number of papers published in the transactions of the Institution and elsewhere, and his list commenced with a paper read before the Royal Society as far back as the year 1827, by Mr. James Walker, Past-President Inst. C. E. A deceased member, Mr. George Parker Bidder, assisted in making the experiments. That, however, was not really a case in point. The experiments were made in the East India Dock Import Basin, Blackwall, which was 1,410 feet long, 560 feet wide, and 24 feet deep. The paper published in the Philosophical Transactions of the Royal Society contained drawings of the two boats experimented upon and the apparatus. These experiments showed that the resistance increased as the square of the velocity, and that at higher velocities it was an increasing resistance. But Mr. Walker had distinctly stated that the resistance would be very much greater in a narrow canal. As to the internal navigations of the country, undoubtedly a great deal might be done in developing some of the early works by increased works, doing away with some of the locks, increasing the cuttings, and mak-

ing them more interchangeable than at present; but the subject was so great that it would certainly form a good theme for an interesting paper. Whatever might be thought in reference to some of the positions of the author, the profession generally, and especially those members of it who were interested in canals, were certainly indebted to the author for having brought the subject forward in the manner he had done.

Mr. J. I. Thornycroft thought that in the theory of resistance as expressed by the author's formula, certain incorrect assumptions were made. One was that the velocity in open water was equal to the velocity of a boat passing through the water of a canal; or, its velocity past the land was equal to the velocity through still water, less the speed of current caused by the vessel past the greatest immersed section. The author had also assumed that an ellipse of equal area afforded the same facility of flow as a circle, and stated that the hydraulic mean depth was the same in a semi-ellipse and a semi-circle of the same area. That he believed to be the case when the depths were equal, but not otherwise. The author had also made the incorrect assumption that the friction at the bottom of the canal was greater with increased depth. That might be so in a very infinitesimal way as far as the water was compressible, but water was usually taken, and might be so taken in that case, to be incompressible. The author's reasoning led to this fallacy, namely, that if an indefinitely wide ellipse were used of a given area, the flow would be the same as in a semi-circular section. It appeared to him doubtful whether a semi-circular section was the best for a canal, but of course it was necessary to consider if it was practicable to make a semi-circular section. He was afraid that engineers would complain of the difficulty of keeping up the banks. In order to approach the subject, he thought it would be well to consider the stream-lines of water and the waves as they occurred in deep, wide water. The subject of the motion of a vessel through water, where the section was not limited, had been studied by many authorities. Professor Rankine had considered the motion of water about a vessel, and Mr. Froude had drawn the lines which the water would take, or rather the form which uniform straight bands of water would take, if the water were limited to motion in a horizontal plane, while a particular solid was moving through the mass, or might be considered as obstructing the flow. Of course that was an assumption to make the matter more simple. The real stream-line motion about a solid was so complicated that he could not define it exactly —only for some limited forms.

When a vessel floated in water with a free surface, waves formed at the bow and stern, which very much complicated the matter; but it might be taken that when a vessel passed through water, the water took part of the motion of the vessel at the bow and stern, and acquired a greater head or higher level, and increased the pressure on the bow and stern; this increase of head was transformed into velocity about the midships portion of the boat, where in deep water it had a distinct motion towards the stern of the vessel as described by the author. That motion in deep water was rapid somewhat near the vessel, gradually tapering off to no motion at a great distance. If a vessel surrounded with water having the motion described, were put into a shallow channel, it was evident that the motion underneath the vessel must be restricted, for part of the water which took motion from the vessel, would be replaced by the solid bottom of the canal, so that the vertical motion at the bow and stern must be obstructed. and a greater motion take place on either side. Mr. Samuda had made a statement (from which he differed) to the effect that water must be compressed in order to pass under a vessel. If a vessel fitted the canal at its sides, only leaving a passage for water underneath, of course the vessel would go along the canal and the water would have to pass under. When a part of the hull of a vessel moved rapidly near the bottom of the canal, there was a rapid motion of water and scouring (perhaps where it was not injurious), and increased motion along the sides of the canal, when compared with the corresponding motion in deep water. In Mr. Samuda's description of a steamer passing over a bank down the river, he had spoken of the vessel being retarded and the paddles going more rapidly. That he took to be an indication that the stream-lines on the

sides of the vessel were more rapid, as previously described, in shallow water than in deep water, and instead of the vessel going faster it was moving more slowly by the land, although the relative motion of the vessel and the water alongside was greater. Mr. Scott Russell had made some valuable experiments on the passage of waves along canals, but he thought the author was right in saying that the waves of translation moved very little water; most of the water had to pass the vessel, and therefore his formula for the motion of the water past the vessel perhaps approximately represented the facts. With regard to the second form of section, it had been argued that a wide section was necessary. He was not sure whether that was so or not, but it was certain that a deep section was necessary, and it seemed to him that if there was about an even depth of water in all directions from the surface of the hull, that was perhaps the most advantageous section, speed alone being considered in a limited section of water. He had observed this in working a steamer in the upper Thames, where there was a canal, a wide stream, and various forms of section. About the locks there was sometimes a deep, narrow section where the boat attained a moderate speed with apparent ease, and the waves ran smoothly along the bank without any breaking or any destructive effect. If the banks were smooth there would be little or no damage done, either to the banks, or the energy in the water which accompanied the vessel. In the Clyde, where rapid steamers were used of great power and the banks were paved, the effect of a vessel going at a high speed in a comparatively small channel might be seen. There was one effect which caused very much retardation where there was shallow water at the side. There were two principal kinds of waves which followed a steamer—those which diverged from the bow, and the transverse waves at the bow and stern, particularly at the stern. The transverse waves, in going along a narrow channel, with somewhat shallow sides, were bent into a curve and retarded, as could be seen on the sea-coast, the waves almost always coming in towards the shore, never making an angle of anything like 90° with the shore. So, in a canal with shallow sides, the waves turned to the shore, ran aground and broke; that used up the force in the waves. The stem and stern waves were necessary; they were a part of the motion of the vessel; they had a *vis viva*, which belonged to the vessel as much as her own motion. Not so with the waves which ran off from the bow to the shore; they must go to the shore. But when the water was deep near the banks the waves would follow the vessel with more ease, and would, he thought, be less destructive. He did not know the object of the wide, shallow water at the sides of the Suez Canal; it would, no doubt, lessen the energy of the diverging waves from the bow, and might be very useful in protecting the soft banks; but it seemed to him that if a greater depth could be given it would be advantageous. With reference to wave motion he would refer to Mr. R. Edmund Froude's paper in 1881, before the Institution of Naval Architects, which gave a clear notion of the waves accompanying a boat. One thing in the author's paper which showed its inefficiency was that as the length of a vessel was varied the attendant waves fell on the vessel differently, and there was a great change in the resistance at any particular speed; now, when a vessel was moved along a canal, there would be a change in the form of the system of waves accompanying her, and the waves would only be repeated in a greater length for a particular speed, so their incidence on the vessel would be changed. This one cause of change alone would make the author's formula complicated, so as to be inapplicable if completely included. But perhaps with a number of experiments some useful rule might be advantageously established.

THE use of an aluminium process for the decoration of iron and steel, as well as for their protection against rust, is spoken of in the German technical press. This process is intended to take the place of nickeling, tinning and coppering. The coating of aluminium is said to leave the sharpness of outline unimpaired, and to adhere very closely, being applicable to both cast and wrought work. Decoration with gold, silver, or vitrifiable pigments is said to be facilitated by this method. It is considered that the high price of aluminium—caused by the expensive processes by which it is made—will not seriously affect the success of this process.

HADFIELD'S PATENT MANGANESE STEEL.

By JOSEPH D. WEEKS, Pittsburgh, Pa.

Transactions of the American Institute of Mining Engineers.

MANGANESE has, until recently, been most highly esteemed as a good thing to keep out of steel. Its value in the process of manufacture has been fully recognized, but after it has played its part in the crucible or the converter, then the less of it the better. It is true that the mission of this metal and its influence upon the character of steel have been a source of much controversy. Our own Holley, in one of his special reports on ferro-manganese, states that "it has been suspected by some, and believed by a few, while it is still denied by many, that manganese as an ingredient in steel has not only a body-giving and toughening influence, but a positive neutralizing influence upon any excess of hardening or cold-shortening substances as phosphorus." In another paper on the same subject he states that "it should appear from such facts as we have that manganese toughens" the structural steels, "increases their soundness and prevents red-shortness." Notwithstanding these rather guarded assertions as to its value, the general belief, it will be found, is with Dr. Siemens, that manganese is "merely a cloak to hide impurities," and its presence in steel has been endured, not welcomed.

But whatever may have been the difference in opinion as to the effect upon steel of a small percentage of manganese, not to exceed, say, 1½ per cent., there has been a general agreement among metallurgists that any amount in excess of this would produce metal rotten and utterly worthless. In the Terre Noire experiments, referred to in Mr. Holley's report before quoted, 1 per cent. is the highest given as found in the steels reported upon. In a paper read by M. Gautier, of Terre Noire, before the British Iron and Steel Institute, on the "Uses of Ferro-manganese," this same percentage is given as the proper amount to be used in the manufacture of what this distinguished metallurgist terms "manganese steels," while in all three of the papers the analyses of the steel show the usual percentage of manganese to be much below this. Indeed, from 1 per cent. to 1½ per cent. has been regarded universally as "high manganese," and the published testimony is that more than this renders steel worthless.

In opposition to these views, Mr. Robert Hadfield, of the Hadfield Steel Foundry Company, Sheffield, England, has demonstrated that a steel containing from 7 to 30 per cent. of manganese is not only not a rotten and worthless product, but that in the ingot, as cast, it is harder, stronger, denser and tougher than most steel now manufactured, even when forged and rolled, and in addition it possesses curious and remarkable properties, which, it is believed, will make this steel exceedingly valuable for many purposes for which the ordinary steels are not now used.

In the samples of steel which, through the kindness of Mr. Hadfield, I am permitted to exhibit to the Institute, the manganese is from 9 per cent. in ingot No. 10 to 19 per cent. in the ax. No samples of the higher percentage have reached me. The bent flat piece contains 9½ per cent.; ingot 180 and the pit car-wheel which has been so badly hammered with so little effect, 11½ per cent.; the adze, 13¾ per cent.; and ingots Nos. 20 and 21, 14½ per cent. The ax and adze are castings just as they came from the sand, neither forged nor hardened, and have been ground since I received them. These are rough specimens, the Hadfield Foundry not being adapted to this class of work, but with proper care in moulding and manufacture, such articles can be made as smooth and clean as cast-iron. Indeed, some of the most valuable characteristics of this steel are shown in casting. It possesses great thinness and fluidity, casts without misrunning, does not settle as much as ordinary castings, and does not draw, particularly at the junction of the thick and thin parts. It is also free from honeycomb and other similar defects.

It is evident that a metal that casts in

this manner, and that needs no hardening nor tempering, must be especially adapted not only to the manufacture of most articles that are now cast, but for a wide range of articles that are now forged, rolled or hammered, such as the larger edged tools, hammers, picks, etc., guns, armor-plate, shell and other projectiles, car-wheels in place of chilled wheels, implements and parts of machinery, especially bearing parts, safes, steel tyres, plow-steel, etc. A razor has been cast from this steel and used without hardening. It was not equal to the best steel razor, but it was a fair implement.

But perhaps the most remarkable and valuable of the properties of Hadfield's steel is its great toughness, combined with its extreme hardness—two properties that are generally regarded as incompatible. The toughness will be evident upon an inspection of the fracture of the ingots. The little steel needles scattered all over the face of the fracture, forming an acute angle with the face, show the character of the rupture to be entirely different from that of ordinary steel. These needles are very tough, and, small as they are, do not break off when struck, but bend almost like native copper. It also requires a blow of considerable force to bend them. It was exceedingly difficult to break these ingots, a number of blows of a steam hammer being required, sledges having no effect. Ingot No. 10, with 9 per cent. of manganese, was broken from a piece 2 feet 6 inches long, supported at both ends. It bent 1½ inches before breaking, though it had not been forged. Hammered samples from this ingot gave 42 tons (94,080 pounds) tensile strength, and 20.85 per cent. elongation in 8 inches. The flat piece—No. 180 (9½ per cent.)—which has been hammered, was bent cold, and does not show the least crack. This piece has been drilled. The bulging of the steel under the drill-point is quite noticeable. This piece of wire was also bent cold after drawing. The small colliery-wheel (11½ per cent.) was struck 50 blows with a heavy sledge, and bent as will be seen.

Notwithstanding this toughness, the steel is extremely hard. The lower percentages—say 9 per cent. to 10 per cent.—which are the toughest, can be drilled and machined, but not as readily as the ordinary steels; those somewhat higher with difficulty, while it is practically impossible to drill, turn or otherwise machine the higher percentages. The colliery-wheel, which bent so under the sledge blows, shows on the head and hub the results of attempts made in this country, at my request, to drill and turn them. The edges were taken off the tools instantly, hardly scratching the wheel. The ax (19 per cent.) and the adze (13¾ per cent.), as has been already stated, were sent me rough as they came from the sand, and were ground by Messrs. Hubbard, Bakewell & Co., Pittsburgh. Regarding the steel, Mr. Charles W. Hubbard writes me:

"The steel ax and adze we ground for you were extremely hard. There seems to be a peculiar close, hard, greasy nature about the materials that resists the action of the grindstone and emery-wheel, as they have less effect on them than anything we have ever seen in the line of steel or iron. I would say the material has the very essence of anti-friction. A journal made of such material would run to an extreme number of revolution in a sand-box without friction or heat."

I have not tested this ax, but one made in a similar way cut through ⅝-inch iron. I have already intimated that this steel can be rolled and forged. The lower percentages are more easily worked, but steel with as much as 18 per cent. has been hammered. The higher percentages require great care, however. One of the most remarkable properties of this steel exhibits itself in connection with hammering or drawing it. When thus manipulated, it becomes exceedingly hard and loses some of its toughness. If now the steel is heated to a hot heat, yellow or nearly welding, and allowed to cool in the air, or is cooled in water or oil, it becomes exceedingly tough. The flat piece, No. 140, was so heated and cooled before heing bent. The wire was similarly treated after drawing, which made it extremely hard. This is virtually annealing, but it will be noticed that it has an effect upon Hadfield's opposite to that upon carbon steel. It should be noted that this steel is non-magnetic in bulk and a poor conductor, though fine drillings and scrapings are attracted by the magnet.

The process of manufacturing this steel is exceedingly simple. Melted ferro-manganese high in manganese (Mr. Hadfield suggests 80 per cent.) and as low as possible in carbon, silicon and other foreign bodies, is added to iron that has been nearly or quite decarburized, or to molten steel. The manganese is thoroughly incorporated by stirring, and the steel poured into ingots or other suitable moulds. The percentage of ferro to be used, and consequently the amount of manganese in the steel, must be raised according to the use to which it is to be put. No absolutely exact proportions can be given. To produce a steel suitable for armor-plates, sufficient ferro to give, say, 10 per cent. manganese in the steel should be added; for car-wheels, axles or railway plant, say 11 per cent.; edge tools and steel tyres, 12 per cent.

THE PROPORTION BETWEEN STRESSES AND SECTIONS IN GIRDER WORK.

From "The Engineer."

Is the existing method of constructing girders by piling and riveting large and comparatively thick plates together followed because experience has proved it to be the best possible, or has mere habit and tradition an influence in its retention? From time to time the question has been discussed whether any better mode of securing ironwork other than by rivets is practicable, and up to the present the resulting verdict is in the negative. We do not purpose to criticize this opinion, but the fastening of the parts of a girder together is only one item in the designing and building of ironwork. The adjustment of good proportions between stresses and the sections resisting them is another and extremely important point, and the question we have put above relates to it. In some treatises on ironwork students are warned against entertaining the idea that it is possible to so design a girder or other similar structure as that every part will be alike in its strength and stress proportion. No doubt, in a certain sense, the warning is deserving of attention, but there is this fault about it that it tends to discourage original thought, and deters students and the younger members of the engineering profession from attempting a closer approximation between stresses and sections than obtains at present. No girder or truss is stronger than its weakest point, and the greater the number of weakest points in a girder the nearer, paradoxical as it may appear, is the approach to proper and economical proportion of material to load. A girder, every foot of which would be its weakest, or strongest, point, would be in this respect perfect; and, reciprocally, any girder having any given point much in excess of all the rest in strength, is, by that excess, showing both a waste of material and an undue loading of the weakest point as well, which, as a consequence must be strong enough to sustain, not alone the legitimate stress due to correct design, but also to carry the weight of the excess material at the point unnecessarily strong, and which may be designated redundant iron. Thus it will be seen that bad proportioning of a girder causes greater waste of material than is superficially apparent; and were any one to set out even a moderately-sized girder, making some one point stronger than all the rest, and were then carefully to investigate the effects of that excess weight of material on other parts, necessitating increased section and consequent weight for them, and the effect of this again elsewhere, results might—nay, would—be found showing that it is very expedient to study proportion in girders with tolerable exactness.

An excellent method of ascertaining at a glance how near to exactness a girder has been proportioned to its total work, is to set out respectively the curves of stresses and the straight lines of resisting sections. We say straight lines of resistance advisedly, for such they are, and this fact seems more or less

ignored by many girder designers. The stresses of a girder, when graphically set out, are almost invariably curves of one or another type. Now, if even a simple girder, loaded uniformly all over, have respectively its stress lines and its resisting lines set out the one on the other, and to a true scale, that is, so that both vertical and horizontal scales are the same, an inspection of them will show that something remains for us to learn in the rolling of plates and angle-irons for such work, and their subsequent distribution in a girder. In a perfect girder to sustain a statical load, the graphic delineation of stresses will show a line more or less curved, the character of the curve depending upon the distribution of the load. The graphic setting out of the sections of resistance will show an exactly similar curve at such a distance from the stress line as would, on the scale adopted, represent the margin of safety adopted. Owing, however, to the present system of constructing girders by fastening a number of plates together, the section or resistance line can never in practice be a curve. It will be a series of straight lines, with abrupt terminations, and under the plate system of construction a designer must first set out his stress line curve, and then so set out his section of resistance lines as that its lowest point will not fall within the margin of safety line he will of course have set out beside the stress line. When this has been done, he will find a rather startling excess of strength in various parts of the lines, all dead or redundant material—"an old man of the sea"—lost money. Mathematicians delight to set out stress curves, and to give their readers and pupils the formulæ from which these have been arrived at. Such work is useful—very large iron structures, in fact, could scarcely be designed without their aid. Fortunately it is easier, so far as statical stress is concerned, to get tolerable uniformity between stress curves and resisting sections in large than can be attained in small work; this, of course, is due to the proportionally greater number of separate parts in the larger structure; or, to put the thing in another way, as each plate is represented by an ordinate from the horizontal datum, the greater the number of plates the greater also the number of ordinates, and one great change of section is subdivided into a greater or less number of smaller changes. It is well known that sudden changes of diameter are carefully to be avoided in shafting, and we now desire to direct the attention of those of our readers who may not thoroughly realize the fact, that just as it is certain that abrupt or even moderately abrupt change in the diameter of a shaft seriously weakens it, so also is it true that the greater are the abrupt changes of resisting section in girder or truss ironwork, so also is the waste of material. The corollary or deduction from this being, that regarded from this point alone, the smaller the plates, and consequently the greater the number used in a girder, the less will be the idle and wasted material present in the work. Other reasons also suggest the advantage of using small and thin in preference to large and thick plates. The former, to begin with, can be had at a lower price; they are more easily made of uniform quality, require less labor to shift, less loss is incurred in a waster—test samples spoiling plates, it is better to spoil a small than a large one; better and sounder riveting can be attained with thin plates, and every plate is more likely to do its fair share of work. It perhaps will be objected that however sound our arguments may be for statical loads, the stresses due to dynamical work are so variable that such reasoning cannot apply. Such an objection has some force, but how much? Rolling, or other loads inducing vibration have their limits just as well defined as have statical stresses, and this being so, the value of the objections possible to raise against our reasoning is capable of determination, and can be so determined by any one expert in calculating dynamical strains. All that is necessary is to set out the dynamical stress curve for a rolling load, and then plotting the resistance section line. The only real force of any objection to the foregoing reasoning is that the calculation of dynamical stress needs a higher order of mathematical proficiency, and that a structure intended for dynamical work must of necessity have much more idle material, or rather much more material idle, when no train or other load is moving over it. In other respects, a neglect of the principles involved in the above reasoning is just

as bad in the one case as in the other. If some of our mathematical readers, or those who make the designing of girders a specialty, will set out the curves of stress and the lines of resistance for a girder, say, of 120 ft. span for such comparatively statical work as a road bridge, and also for a railway, we shall be happy to publish them and open our columns to a discussion on the merits of thick *versus* thin, and small *versus* large plates in girder work.

Another point deserving of attention at the hands of bridge and girder designers is the consideration of how far equality of resisting section to stress may be more nearly attained by using plates of different sizes and thicknesses. Conditions of working might, and no doubt do, arise in which variation of sizes and thicknesses would economize material if adopted. The distribution of iron to the greatest advantage, and how best to effect it, is a field of investigation in which both the theorist and the practical man can work together, and which indeed must be worked by both jointly if the best results are to be attained. It is a branch of study in which one cannot do without the other. A good deal may be, and doubtless is, already known on the subject, but it is certain something remains to be learned.

A NEW FORMULA FOR THE CALCULATION OF DRAW-BRIDGE STRAINS.

By F. BERESFORD, C. E., Cincinnati, Ohio.

Written for Van Nostrand's Engineering Magazine.

In 1857 Clapeyron published his celebrated "Theorem of Three Moments." Since then it has been greatly improved, but mostly by German and French workers in this department of Applied Mathematics.

In 1873 Weyrauch published a very complete work on the subject in which he considered the Moment of Inertia as variable instead of constant, as it had been taken previous to this time. Prof. Eddy has also made some additions to the formula, so that in its present form it is almost perfect in its applications to continuous girders. However, when it is used in the calculation of Draw-Bridge Reactions and Moments, it is found to be faulty for the following reasons:—

1st. The area of cross-section of the chords is assumed to be constant throughout the entire bridge; this in itself is, in our opinion, sufficient to condemn its use. Practically it is found that the area of cross-section of chord of the last panel of the first span (counting both panels and spans from left to right) may be at least ten times that of the first panel, that of the intermediate panels being between the first and last and increasing as we approach the center of the bridge.

2d. It considers the bridge to be of uniform height and makes no provision for a slanting chord member. As it is often found convenient, as a matter of economy, to have one chord slanting, the importance of this question is at once apparent.

3d. It neglects the deflections due to the web members, a matter of considerable importance, when the chords are not parallel.

4th. In the equation for the deflection $\frac{1}{r}=\frac{d^2y}{dx^2}=\frac{M}{EI}$, the one upon which the "Theorem of Three Moments" depends, the Moment of Inertia (I) appears either as a constant or variable factor. The Moment of Inertia of a beam or girder is, we think, well understood, but never, so far as we know, has any person defined the Moment of Inertia of a *truss*.

$$(\text{Area of cross-section of chord})\times\frac{(\text{height})^2}{2}$$

is generally given as the value of the Moment of Inertia, but it has not been proved to be correct. Indeed, there is great doubt as to its correctness. Until we have a value which is known to be correct, it is not wise to use it.

It is the object of this paper to obtain a formula that will as far as possible, be free from these sources of error. We know that, at best, it will be but an approximation, but, nevertheless, we hope that it will give results nearer the truth than any heretofore obtained.

Mr. Chas. Bender, C. E., has, in his discussion of the "Properties of Continuous Bridges," incidentally derived the "Theorem of Three Moments" in such a manner as to be well suited for the present purpose, and we shall in general pursue the same method as that adopted by him.

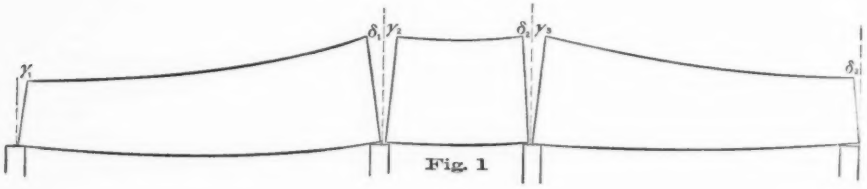


Fig. 1

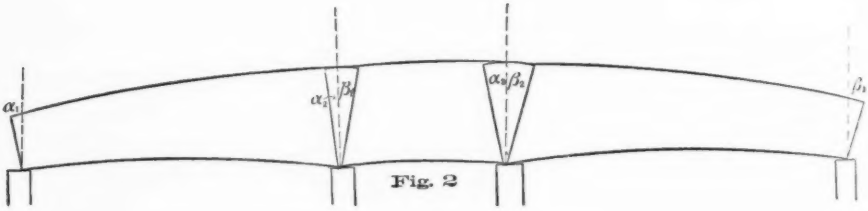


Fig. 2

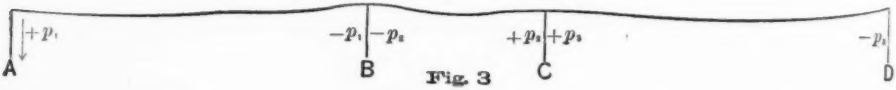


Fig. 3

Suppose the bridge to rest upon four points of support, thus making it consist of three spans. Now conceive for an instant these spans to be simple trusses, not fastened together at the piers. If these trusses are not loaded, the posts over the piers will remain vertical; but by loading them in any possible manner, the posts will, by reason of deflection of the trusses, make certain angles with their originally vertical positions. The value of these angles depends on—the length of truss, the height at the different panel points, the character of the loading and the quality of the material.

Let these angles be represented by γ_1, γ_2, γ_3, δ_1, δ_2, δ_3, as in Fig. 1.

Now by exerting on the top of the end post at the pier B or C, A, B, C, and D, being the piers upon which the bridge is supported, a certain tensile strain and at the bottom of the same post a compressional strain equal in amount, we can cause the sum of the angles $(\delta_1+\gamma_2)$ or $(\delta_2+\gamma_3)$ to become zero. This is in reality what occurs when a bridge is made continuous. Then we have the ends so fastened together that there can be no angle between the end posts; this causes, when the bridge is loaded, certain unknown moments at the piers depending upon the forces above mentioned.

These forces would, were the dead and live loads removed, cause certain upward flexures due to the unknown moments, and therefore, cause the end to make angles α_1, α_2, α_3, and β_1, β_2, β_3, of Fig. 2 with their vertical positions.

Over one pier we have: The sum of the angles due to flexure is equal to that due to deflection, that is

$$\alpha_2+\beta_1=\delta_1+\gamma_2 \text{ and } \alpha_2+\beta_2=\delta_2+\gamma_3. \quad (1)$$

By means of these fundamental relations we propose to obtain our formula. The second members are in terms of known loads at known distances from the piers, and the first are in terms of the unknown moments, the values of which give a solution to the problem, since the

reactions at the piers can at once be found from them.

Suppose h_b to be the height of the bridge at pier B and f the force referred to above, which acts along the horizontal chord, then,

$f\ h_b = \mathrm{M}_b$, M_b representing the moment producing upward flexure and acting at the pier B. By the principles of Statics, we have

$\mathrm{M}_b = p_1\, c_1\, n_1$, p_1, c_1, n_1, representing, a force acting vertically at the pier A, the panel length, and the number of panels of the first truss, respectively.

In the continuous truss, Fig. 3, we must have at the pier B, in order to preserve equilibrium, such a moment, that being added to M_b will give zero, and since $c_1 n_1$ is the same in both cases, the force must be $-p$, that is, it acts in a direction opposite to the one at A. By similar reasoning it can be shown that $-p_2$, $+p_2$, $-p_3$, $+p_3$, act at B, C, and D, as shown in the figure.

We have the equations

$$\left.\begin{aligned} \mathrm{M}_b &= p_1\, c_1\, n_1 \\ \mathrm{M} &= \mathrm{M}_b - p_2\, c_2\, n_2 \end{aligned}\right\} \quad . \quad . \quad . \quad (2)$$

M_c being the moment at the pier C and subscript $_2$ being used for middle span.

Since at the end piers the arm of the force is zero, the moments at these points are each zero and no bending moment occurs there.

Before obtaining the values of α, β, γ, δ, it will be necessary to make several auxiliary proofs, with which we will now proceed.

1st. Let A B C be any triangle, a, b, c, being the sides as shown in Fig. 4, then,

$$a^2 = b^2 + c^2 - 2\,bc \cos. \mathrm{A}.$$

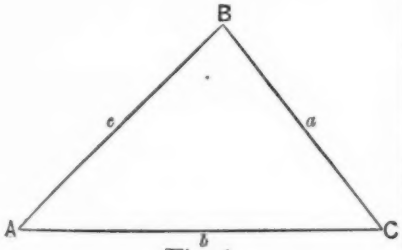


Fig. 4

If under the action of a certain force the length of the side a is changed by Δa, that of b by Δb and that of c by Δc making the total lengths $a+\Delta a$, $b+\Delta b$, $c+\Delta c$, then

$$(a+\Delta a)^2 = (b+\Delta b) + (c+\Delta c)^2 - 2(b+\Delta b)(c+\Delta c) \cos. (\mathrm{A}+\Delta \mathrm{A})$$

A being at the same time changed by ΔA

$$a^2 + 2a\,\Delta a + (\Delta a)^2 = b^2 + 2b\,\Delta b + (\Delta b)^2 + c^2 + 2c\Delta c + (\Delta c)^2 - 2(bc + b\Delta c + c\Delta b + \Delta b \Delta c) \cos. (\mathrm{A}+\Delta \mathrm{A})$$

Since Δa, Δb, Δc, are, at most, exceedingly small quantities, the squares and products of them can, by the principles of Differential Calculus, be neglected.

As ΔA is also very small cos. ΔA=1 and sin. ΔA=ΔA.

$$\therefore\ a\Delta a = b\Delta b + c\Delta c - (b\Delta c + c\Delta b) \cos. (\mathrm{A}+\Delta \mathrm{A}),\ bc \text{ sin. A},$$

or $\Delta \mathrm{A} =$

$$\frac{a\Delta a - b\Delta b - c\Delta c + (b\Delta c + c\Delta b) \cos. \mathrm{A}}{bc \text{ sin. A}}.$$

If A=90° then

$$\angle \mathrm{A} = \frac{a\,\triangle a}{bc} - \frac{\triangle b}{c} - \frac{\triangle c}{b}$$

$$\triangle \mathrm{B} = \frac{\triangle b}{c} - \frac{a\,\triangle a}{bc} + \frac{c\,\triangle a}{ab} = \frac{\triangle b}{c} - \frac{(a^2 - c^2)}{abc}\Delta a$$

$$= \frac{\triangle b}{c} - \frac{b\,\triangle a}{ac} \text{ since } a^2 - c^2 = b^2$$

$$\triangle \mathrm{C} = \frac{\triangle c}{b} - \frac{c\,\triangle a}{ab}$$

2d. Let A, B, C, be the three angles about the x^{th} panel point of an unloaded truss, and θ_x the angle which the upper chord at this point makes with the lower.

As the bridge is unloaded the lower chord members lie in a straight line, or

$$\mathrm{A}+\mathrm{B}+\mathrm{C} = 180° \text{ and } \mathrm{A} = 90°.$$

but when a load is applied each angle is changed by a very small amount, so that,

$$\mathrm{A}+\Delta\,\mathrm{A}+\mathrm{B}+\Delta\,\mathrm{B}+\mathrm{C}+\Delta\,\mathrm{C} = 180°$$

Let $\Delta\,\mathrm{A}+\Delta\,\mathrm{B}+\Delta\,\mathrm{C} = \delta$.

From Fig. 5 in which d_x, d_{x+1}, are the diagonals, h_x, h_{x+1}, the posts, and c_x, c_{x+1} the lower chords, we see from the previous problem that

$$\Delta \mathrm{A} = -\frac{\Delta\, h_x}{c} - \frac{\Delta\, c_x}{h_x} + \frac{d_x\, \Delta\, d_x}{h_x\, c_x}$$

$$\Delta \mathrm{B} = \frac{\varepsilon_x\, \Delta\, \varepsilon_x - d_{x+1} \Delta\, d_{x+1} - h_x\, \Delta\, h_x}{c\, h_x} + \frac{(d_{x+1} \triangle h_x + h_x\, \triangle d_{x+1})\, h_{x+1}}{c\, h_x\, d_{x+1}}$$

$$\Delta C = \frac{\Delta h_{x+1}}{c} \quad \frac{-\Delta d_{x+1} h_{x+1}}{c\, d_{x+1}}, \text{ so that}$$

$$\delta_x = \frac{\text{Sec. } \theta_x \ \Delta \varepsilon_x - \Delta c_x}{h_x}$$

$$= \frac{d_x \Delta d_x - d_{x+1} \Delta d_{x+1} + h_x \Delta h_{x+1} + h_{x+1} \Delta h_x - 2 h_x \Delta h_x}{c\, h_x}$$

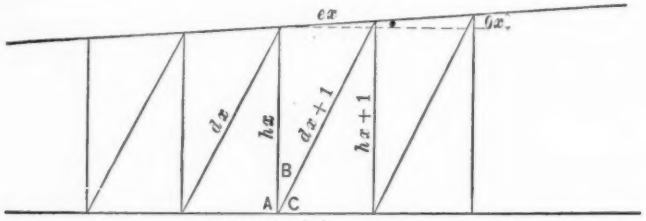
In the above value of δ_x the first term of the second member is the amount due to the chord members. This while seemingly a difference is really a sum, for, the first term of the numerator of this fraction expresses the change of length in the upper chord, due to compression.

The second term of the second member of this equation, the part due to the web strains, has the + sign when the diagonals are tension members and the posts compression members, and the − sign when the reverse is true.

Now $h_{x+1} - h_x = c \tan. \theta_x$ and $h_{x+1} + h_x (1+2\lambda) = 2(1+\lambda) h_x$ nearly, hence this term becomes

$$\pm \frac{R'}{E} \cdot 2(1+\lambda) \tan. \theta_x \text{ nearly, and}$$

$$\mu_x = \frac{R'}{E}\left(c \frac{(\lambda \sec.^2 \theta_x + 1)}{h_x} \pm 2(\lambda+1) \tan. \theta_x\right) \text{ nearly} \quad . \quad . \quad . \quad (3)$$



$cx = cx + 1$

Fig. 5

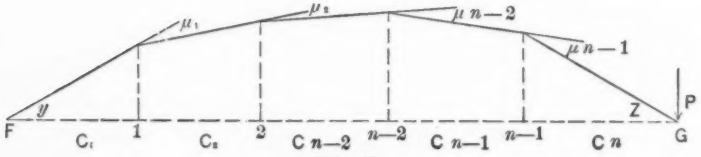


Fig. 6

The second term expresses that in the lower chord due to tension. If we consider compression as a positive strain and tension as a negative, the first term becomes the sum of two quantities.

In any piece of material the change of length due to a compressional strain is equal to $\frac{l \times \text{Stress}}{E \times \text{Area}} = \frac{R\, l}{E}$, that due to a tensile strain is equal to $\frac{R' l}{E}$, in which R is the proof strength for compression, of the material, R′ the same for tension, l the length of the piece, and E its Modulus of Elasticity. Let $\frac{R}{R'} = \lambda$ then

$$\mu_x = \frac{c\, R'}{E\, h_x}(\lambda \sec.^2 \theta_x + 1) \pm R'(h_{x+} \quad _x) [h_{x+1} + (1+2\lambda) h_x].$$

3d. If $\mu_1, \mu_2, \mu_3, ---- \mu_{n-1}$ represent the angles which the lower chord members make with each other after the truss has been bent, as in Fig. 6, and y and z the angles which the end members make with the straight lines joining the two end panel points, then

$$y + z = \mu_1 + \mu_2 + \mu_3 + + + ---- \mu_{n-1},$$

and

$$y + (y - \mu_1) + (y - \mu_1 - \mu_2) + + ---- (y - \mu_1 - \mu_2 - \mu_3 --- ^{n-1}) = 0$$

For the lower chord members

$$c_1, c_2, c_3, --- c^{n-1}$$

are of the same length, thus making the sum of the sines of all these angles equal to zero, and as the angles are very small, we may use them instead of their sines.

$\therefore ny=(n-1)\mu_1+(n-2)\mu_2+(n-3)\mu_3+\text{- - - - -}2\mu_{n-2}+\mu_{n-1}$

and $nz=\mu_1+2\mu_2+3\mu_3+\text{- - -}+(n-1)\mu_{n-1}$

$$y=\frac{1}{n}\sum_1^{n-1}(n-x)\mu_x \text{ and } z=\frac{1}{n}\sum_1^{n-1}x\mu_x. \quad (4)$$

If at the end of the n^{th} panel, or at the point G, a force P acts as in Fig. 6, then the stress on any horizontal member due to this force is P × distance from point of application of P to member in question $\times \frac{1}{\text{height at this pt.}}$, or, if the panel pts. be numbered 1, 2, 3, 4, etc., from left to right, as in the figure, then stress on the x member $=\frac{P(n-x)c}{h_x}$. Substituting the value of R′ in equation (3) and value of μ_x in equation (4) we have

to a load W concentrated at one of the panel points, and from this find the effect of the loads concentrated at the other panel points, and thus of the whole load causing the deflection.

Suppose the curved line FG, in Fig. 7, to represent a curve passing through the lower panel points after the load W has been applied, and H.I. the tangent to the curve at the point of application of the load, distant mc from the pier G.

The problem really becomes the following:

1st. To find the angles y and z of the two segments of the truss, mc, and $(n-m)c$.

2d. To find the values of the angles Ψ and φ, as shown in Fig. 7, in terms of y and z. Ψ and φ, being the angles which lines drawn to join the two end panel points, and the panel point at H

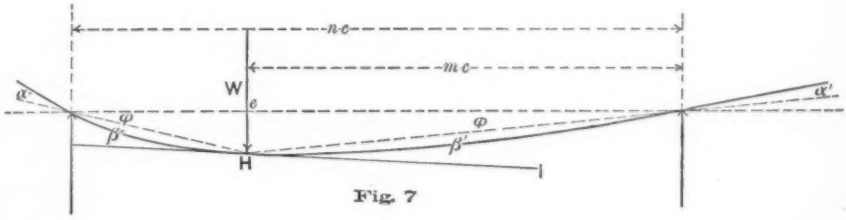


Fig. 7

$$y=\frac{-Pc}{En}\sum_1^{n-1}\frac{(n-x)^2}{h_x^2 A_x}\left[c(\lambda \sec.^2\theta_x+1)\mp 2(\lambda+1)h_x \tan.\theta_x\right]$$

$$z=\frac{-Pc}{En}\sum_1^{n-1}\frac{x(n-x)}{h_x^2 A_x}\left[c(\lambda \sec.^2\theta_x+1)\mp 2(\lambda+1)h_x \tan.\theta_x\right]$$

A_x being the area of the x^{th} section of chord. Since the moment at F is Pcn we have

$$y=\frac{-M}{En^2}\sum_1^{n-1}\frac{(n-x)^2}{h_x^2 A_x}\left[c(\lambda \sec.^2\theta_x+1)\mp 2(1+\lambda)h_x \tan.\theta_x\right]. \quad (5)$$

and $$z=\frac{-M}{En^2}\sum_1^{n-1}\frac{x(n-x)}{h_x^2 A_x}\left[c(\lambda \sec.^2\theta_x+1)\mp 2(1+\lambda)h_x \tan.\theta_x\right]. \quad (6)$$

We can now find the values of α, β, γ, δ.

γ and δ, it will be remembered, are angles caused by the deflection of the truss. To find their values: Conceive the truss to be loaded in any possible manner. First, consider the effect due to a load W concentrated at one of the panel points, and from this find the effect of the loads concentrated at the other panel points, and thus of the whole load causing the deflection.

Suppose the curved line FG, in Fig. 7, to represent a curve passing through the lower panel points after the load W has been applied, and H.I. the tangent to the curve at the point of application of the load, distant mc from the pier G.

The problem really becomes the following:

1st. To find the angles y and z of the two segments of the truss, mc, and $(n-m)c$.

2d. To find the values of the angles Ψ and φ, as shown in Fig. 7, in terms of y and z. Ψ and φ, being the angles which lines drawn to join the two end panel points, and the panel point at H make with the line joining the two end panel points.

In the above figure *β',β'' are y angles while α',α'' are z angles.

$\therefore$ From equation (5)

$$\beta'=\frac{M}{Em^2}\sum_1^{m-1}\frac{(m-x)^2}{h_x^2 A_x}\left[c(\lambda \sec.^2\theta_x+1)+2(\lambda+1)h_x \tan.\theta_x\right]$$

$$\beta''=\frac{M}{E(n-m)^2}\dagger\sum_1^{n-m-1}\frac{x(x+1)}{h_x^2 A_{x+1}}\left[c(\lambda \sec.^2\theta_x+1)-2(\lambda+1)h_x \tan.\theta_x\right] \text{ and}$$

$$\alpha'=\frac{M}{Em^2}\sum_1^{m-1}x(m-x)\left[c(\lambda \sec.^2\theta_x+1)-2(\lambda+1)h_x \tan.\theta_x\right]$$

$$\alpha''=\frac{M}{E(n-m)^2}\sum_1^{n-m-1}(1+x)(n-m-x)\left[c(\lambda \sec.^2\theta_x+1)+2(\lambda+1)h_x \tan.\theta_x\right]$$

* The angles are called β', β'', α', α'' merely for convenience, and should not be confused with α and β mentioned above.

† x is hereby replaced by $x+1$ because the arm of the force is $c(x+1)$ instead of cx.

In obtaining a' and β' the first panel point to the right of the point of application of W is marked 1 and so on.

But $$M=\frac{Wm(n-m)c}{n}$$

$$\beta'=\frac{W(n-m)c}{Emn}\sum_{1}^{m-1}\frac{(m-x)^2}{h_x^2 A_x}$$
$$[c(\lambda \sec.^2\theta_x+1)+2(\lambda+1)h_x \tan.\theta_x]$$

$$\beta''=\frac{Wmc}{E(n-m)n}\sum_{1}^{n-m-1}\frac{x(x+1)}{h_x^2 A_{x+1}}$$
$$[c(\lambda \sec.^2\theta_x+1)-2(\lambda+1)h_x \tan.\theta_x]$$

$$a'=\frac{W(n-m)c}{Emn}\sum_{1}^{m-1}\frac{x(m-x)}{h_x^2 A_x}$$
$$[c(\lambda \sec.^2\theta_x+1)+2(\lambda+1)h_x \tan.\theta_x]$$

$$a''=\frac{Wmc}{E(n-m)n}\sum_{1}^{n-m-1}(1+x)(n-m-x)$$
$$[c(\lambda \sec.^2\theta x+1)+2(\lambda+1)h_x \tan.\theta_x]$$

To find Ψ and Φ, let w be the angle which the two lines, drawn from the end panel points to the point of application of the load, make with each other, and as β' and β'' are angles which they make with the tangent HI, therefore,

$$w+\Phi+\Psi=180°, \quad \text{and}$$
$$w+\beta'+\beta''=180°.$$
$$\therefore\ \beta'+\beta''=\Phi+\Psi$$

Since Φ and Ψ are very small angles they can be taken as proportional to their tangents without appreciable error

$$\therefore\quad \Psi:\Phi::\frac{\varepsilon H}{mc}:\frac{\varepsilon H}{(n-m)c} \text{ or}$$

$$(n-m)\Phi=m\Psi \qquad \Psi=\frac{n-m}{m}\Phi$$

$$\therefore\ \Phi=\frac{m}{n}\left(\beta'+\beta''\right)\text{and } \Psi=\frac{n-m}{n}\left(\beta'+\beta''\right)$$

so that

$$\Phi=\frac{W(n-m)c}{En^2}\sum_{1}^{m-1}\frac{(m-x)^2}{h_x^2 A_x}$$
$$[c(\lambda \sec.^2\theta_x+1)+2(\lambda+1)h_x \tan.\theta_x]$$
$$+\frac{Wm^2c}{E(n-m)n^2}\sum_{1}^{n-m-1}\frac{x(x+1)}{h_x^2 A^{x+1}}$$
$$[c(\lambda \sec.^2\theta_x+1)-2(\lambda+1)h_x \tan.\theta_x]$$

$$\Psi=\frac{W(n-m)^2c}{Emn^2}\sum_{1}^{m-1}\frac{(m-x)^2}{h_x^2 A_x}$$
$$[c(\lambda \sec.^2\theta_x+1)+2(\lambda+1)h_x \tan.\theta_x]$$
$$+\frac{Wmc}{En^2}\sum_{1}^{n-m-1}\frac{x(x+1)}{h_x^2 A^{x+1}}$$
$$[c(\lambda \sec.^2\theta_x+1)-2(\lambda+1)h_x \tan.\theta_x]$$

If the posts remained perpendicular to the chord during deflection or upward flexure then δ would be equal to $(\Psi+a')$, and γ would be equal to $(\Phi+a'')$, for $(\Psi+a')$ and $(\Phi+a'')$ give the proper values of the deflection from the horizontal line of the two end chord members, and if the angle between the end posts and chord members remained constant throughout, it would also express the deflection of the end posts from their originally vertical positions. We have seen, however, that in any right triangle of which the angle A=90° that

$$\triangle A=\frac{-\triangle h_x}{c_x}-\frac{\angle c_x}{h_x}+\frac{d_x \angle d_x}{c_x h_x}$$
(see Fig. 5).

$\triangle A=-\dfrac{h_x^2 R+c_x^2 R'-d_x^2 R'}{Ec_x h_x}$, if c_x is a tension member, which is the case when the truss is deflected by a load,

$$\triangle A=-\frac{h_x}{c_x}R'(\lambda+1)$$

When the truss has an upward flexure, the member c_x is a compression piece, and we have

$$\triangle A=\frac{-h_x^2 R-c_x^2 R-d_x^2 R'}{Ec_x h_x}=-\frac{(h_x^2+c_x^2)}{c_x h_x}$$
$$R'(\lambda+1)=-\left(\frac{h_x}{c_x}+\frac{c_x}{h_x}\right)R'(\lambda+1)$$

From this it is seen that this change of angle tends to increase the value of δ and γ while it increases that of a and β also.

Applying the above principles to finding the values of δ_1 and γ_2 of Fig. 1 due to a load W_1 on the first truss distant m_1c_1 from the pier B, and to a load W_2 on the second truss distant m_2c_2 from the pier c.

$$\delta_1=\frac{W_1}{E}\Bigg\{\frac{m(\lambda+1)}{An}+\frac{mc}{n_1^2}\sum_{1}^{n-m-1}\frac{x'(x+1)}{h_x^2 A_{x+1}}$$
$$[c(\lambda \sec.^2\theta_x+1)-2(\lambda+1)h_x \tan.\theta_x]$$
$$+\frac{n_1-m}{n_1^2}c\sum^{m-1}\frac{(m-x)(n-m+x)}{h_x^2 A_x}$$
$$[c(\lambda \sec.^2\theta_x+1)+2(\lambda+1)h_x \tan.\theta_x]\Bigg\}$$

In the value of δ_1 of the letters $n_1 m$, etc., refer to the first truss, while in the value of γ_2 they refer to the second.

Now, due to the whole loads ΣW_1 and ΣW_2, we will have

$$\delta_1=\Sigma\frac{W_1}{E}\Big\{\frac{m(\lambda+1)}{An}+\frac{mc}{n_1^2}\Sigma_1^{n_1-m-1}\frac{x(x+1)}{h_x\,A_{x+1}}$$
$$[c(\lambda\sec.^2\theta_x+1)-2(\lambda+1)h_x\tan.\theta_x]$$
$$+\frac{(n_1-m)}{n_1^2}c\,\Sigma_1^{m-1}\frac{(m-x)\,(n-m+x)}{h_x^2\,A_x}$$
$$[c(\lambda\sec.^2\theta_x+1)+2(\lambda+1)h_x\tan.\theta_x]\Big\}$$

$$\text{and }\gamma_2=\Sigma\frac{W_2}{E}\Big\{\frac{(n_2-m)\,(\lambda+1)}{A_1}+$$
$$+\frac{(n_2-m)}{n_2^2}c\,\Sigma_1^{m-1}\frac{(m-x)^2}{h_x^2\,A_x}$$
$$[c(\lambda\sec.^2\theta_x+1)+2(\lambda+1)h_x\tan.\theta_x]$$
$$+\frac{mc}{n_2^2}\Sigma_1^{n-m-1}\frac{(x+1)\,(n_2-x)}{h_x^2\,A_{x+1}}$$
$$[c(\lambda\sec.^2\theta_x+1)-2(\lambda+1)h_x\tan.\theta_x]\Big\}$$

We have now to find the values of β_1 and α_2 of Fig. 2. β_1 is caused by the unknown moment M_b acting at the pier β while α_2 is caused by M_b acting at the same pier together with M_c acting at the pier C.

$$\beta_1=-\frac{M_b}{E}\Big\{\frac{(h_n^2+c^2)(\lambda+1}{c_1h_{n_1}^2A_{n1}}+$$
$$+\frac{1}{n_1^2}\Sigma_1^{n_1-1}\frac{x(x+1)}{h_x^2\,A_{x+1}}$$
$$[c(\lambda\sec.^2\theta_x-1)-2(\lambda+1)h_x\tan.\theta_x]$$

$$\alpha_2=-\frac{M_b}{E}\Big(\frac{(h_0^2+c^2)(\lambda+1)}{ch_0^2\,A_1}$$
$$+\frac{1}{n_2^2}\Sigma_1^{n_2-1}\frac{(n_2-x)^2}{h_x^2\,A_x}$$
$$[c(\lambda\sec.^2\theta_x+1)-2(\lambda+1)h_x\tan.\theta_x]\Big)$$
$$-\frac{M_c}{E}\Big(\frac{(h_n^2+c)(\lambda+1)}{c\,h_{n_2}^2\,A_{n2}}+\frac{1}{n^2}\Sigma_1^{n_2-1}\frac{x(n_2-x)}{h_x^2\,A_x}$$
$$[c(\lambda\sec.^2\theta_x+1)-2(\lambda+1)h_x\tan.\theta_x]\Big)$$

In the value of β_1 the letters all refer to the first truss, while in the value of α_2 they refer to the second. Substituting these values of α_2 β_1, γ_2 and δ_1 in eq. (1), we get by assuming the area of cross-section of chord (A) to be constant throughout the lower chord of the middle truss and equal to the area cross-section of the last chord of the first truss while the areas of the others decrease in regular order as we approach the pier A, each one being $\frac{2}{3}$ of the preceding:

$$M_b\Big\{\frac{(h_x^2+c^2)(\lambda+1)}{c\,h_n^2}+\frac{1}{n_1^2}\Sigma_1^{n_1-1}\frac{x(x+1)}{h_x^2(\frac{2}{3})^{n_1-x+1}}$$
$$[c(\lambda\sec.^2\theta_x+1)-2(\lambda+1)h_x\tan.\theta_x]\Big\}$$
$$+M_b\Big\{\frac{(h_0^2+c^2)(\lambda+1)}{c\,h_0^2}+\frac{1}{n_2}\Sigma_1^{n_2-1}\frac{(n_2-x)^2}{h_x^2}$$
$$[c(\lambda\sec.^2\theta_x+1)-2(\lambda+1)h_x\tan.\theta_x]\Big\}$$
$$+M_c\Big\{\frac{(h_n^2+c^2)(\lambda+1)}{c\,h_n^2}+\frac{1}{n_2}\Sigma_1^{n_2-1}\frac{x(n_2-x)}{h_x^2}$$
$$[c(\lambda\sec.^2\theta_x+1)-2(\lambda+1)h_x\tan.\theta_x]\Big\}$$
$$+\Sigma W_1\Big\{m(\lambda+1)+$$
$$\frac{mc}{n_1^2}\Sigma_1^{n_1-m-1}\frac{x(x+1)}{h_x^2(\frac{2}{3})^{(n-m-x+1}}$$
$$[c(\lambda\sec.^2\theta_x+1)-2(\lambda+1)h_x\tan.\theta_x]$$
$$+\frac{(n_1-m)}{n_1^2}\Sigma_1^{m-1}\frac{(m-x)(n-m+x)}{h_x^2(\frac{2}{3})^{m-x}}$$
$$[c(\lambda\sec.^2\theta_x+1)+2(\lambda+1)h_x\tan.\theta_x]\Big\}$$
$$+\Sigma W_2\Big\{(n_2-m)\,(\lambda+1)+$$
$$\frac{(n_2-m)}{n_2}c\,\Sigma_1^{m-1}\frac{(m-x)^2}{h_x^2}$$
$$[c(\lambda\sec.^2\theta_x+1)+2(\lambda+1)h_x\tan.\theta_x]$$
$$+\frac{mc}{n_2^2}\Sigma_1^{n_2-m-1}\frac{(x+1)\,(n_2-x)}{h_x^2}$$
$$[c(\lambda\sec.^2\theta_x+1)-2(\lambda-1)h_x\tan.\theta_x]\Big\}=0.$$

It is often the case that the second span consists of but one panel; then the loading rests directly on the piers and $\Sigma W_2=0$. The y and z angles of this span also become zero.

$$M_b\Big\{\frac{(h_n^2+c_1^2)\,(\lambda+1)}{ch_{n_1}^2}+$$
$$\frac{1}{n_1^2}\Sigma_1^{n_1-1}\frac{x(x+1)}{h_x^2(\frac{2}{3})^{n_1-x+1}}$$
$$[c\,(\lambda\sec.^2\theta_x+1)-2(\lambda+1)h_x\tan.\theta_x]\Big\}$$
$$+M_b^*\frac{(h_0^2+c^2)\,(\lambda+1)}{ch_0^2}+M_c^*\frac{(h_1^2+c^2)\,(\lambda+1)}{ch_1^2}$$
$$+\Sigma W_1\Big\{M(\lambda+1)+\frac{mc}{n_1^2}\Sigma_1^{n_1-m-1}\frac{x(x+1)}{h_x^2(\frac{2}{3})^{n-x-1}}$$
$$[c(\lambda\sec.^2\theta_x+1)-2(\lambda+1)h_x\tan.\theta_x]$$

* h and c of these two terms belong to the second span.

$$+\frac{(n_1-m)}{n_1^2}\,c\,\Sigma_1^{m-1}\frac{(m-x)\,(n-m+x)}{h_x^2\,(\frac{2}{3})^{m-x-1}}$$

$$[c(\lambda\sec.^2\theta_x+1)+2(\lambda+1)h_x\tan.\theta_x]\Big\}=0$$

In practice it is usual to make the third span of the same length as the first, therefore, if we now begin at the pier furthermost to the right and work towards the left, we shall get an equation like the above, except M_c will exchange places with M_b. We now have two equations from which can be obtained by elimination the value of either moment. In case of a pivot bridge, which consists of but two equal spans, the moment at C=o if A, B, C are the points of support, and supposing the areas of the cross-sections of the chords to decrease to the right in the second span as they did in the first span of the three-span bridge, we have:

$$2\,M_b\left\{\frac{(h_n^2+c^2)\,(\lambda+1)}{ch_n^2}+\right.$$

$$\frac{1}{n_1^2}\,\Sigma_1^{n_1-1}\frac{x(x+1)}{h_x^2(\frac{2}{3})^{n-x-1}}$$

$$\left.[c(\lambda\sec.^2\theta_x+1)-2(\lambda+1)h_x\tan.\theta_x]\right\}$$

$$+\Sigma(W_1+W_2)\left\{m(\lambda+1)+\right.$$

$$+\frac{mc}{n_1^2}\,\Sigma_1^{n-m-1}\frac{x(x+1)}{h_x^2(\frac{2}{3})^{n-x-1}}$$

$$[c(\lambda\sec.^2\theta_x+1)-2(\lambda+1)h_x\tan.\theta_x]$$

$$+\frac{(n-m)}{n_1^2}\,c\,\Sigma_1^{m-1}\frac{(m-x)(n-m+x)}{h_x^2(\frac{2}{3})^{m-x}}$$

$$\left.[c(\lambda\sec.^2\theta_x+1)+2(\lambda+1)h_x\tan.\theta_x]\right\}=0$$

In the above investigation it has been supposed that the tops of the piers were at the same height above any horizontal datum plane.

If this is not the case we shall have some additional moments at the piers, for the end posts would no longer be parallel to each other, were the trusses simple and unloaded, but certain angles $(\delta_{a_1}+\gamma_{a_2})$ and $(\delta_{a_2}+\gamma_{a_3})$ would exist which must be made zero, in order to make the bridge continuous. To do this we must add some additional moments M_{aB} and M_{ac} at the piers B and C. We have in this case δ and γ for any one span equal, that is $\delta_{1a}=\gamma_{1a}$, &c.

If we suppose the datum plane to beat the top of the pier A or first pier, it either cuts or passes over the other piers according as they are higher or lower than the first. If k_x represents of x^{th} pier above the datum plane, then,

$$\gamma_{ax}=\delta_{ax}=\pm\frac{(k_x-k_{x-1})}{c_{x-1}-n_{x-1}}$$

Since the angles are very small and we make no appreciable error in taking the tangent of an angle instead of the angle. The + sign being used when the pier in question is higher than the datum plane and the − sign when it is lower.

Substituting in eq. (1) these values of δ and γ, and also of α and β in terms of the unknown moments we are enabled to obtain two equations in terms of the additional unknown moments, from which we can find their values.

As a practical example let us take the bridge computed by Burr* and find the values of the moments.

The bridge consists of three spans. The first and third, each consisting of 6 panels of 24 ft. each, the second, of 1 panel of 8 feet. In the first span $h_1=21$ ft., $h_2=23$ ft., $h_3=25$ ft., $h_4=27$ ft., $h_5=29$ ft., while the height of the second span is constant 30 ft. The load is 18 tons per panel pt. throughout the entire bridge. In this case we have $M_b=M_c$. Substituting in the formula

we have M_b $(.200+.428+.143)=$

$$-18[\tfrac{8}{5}\dagger\,(5+4+3+2+1)+$$

$$\tfrac{8}{3}\tfrac{4}{5}\,(10\times.143+6\times1.121+3\times1.237+$$

$$1.119+2.128+3\times1.369+$$

$$6\times.704+10\times.256)]$$

$\therefore$ $M_b=-965.20$ foot tons. The value given by Burr is -1668.73 foot tons.

* Stresses in Bridge and Roof Trusses, pages 113, 119, and 120.

† In this problem the proof strength for compression is taken as 6000 per sq. in., that for tension 10000, thus making $\lambda=\frac{3}{5}$.

At a recent meeting of the Paris Academy of Sciences, an account was read of a deposit of saltpetre in the neighborhood of Cochabamba, Bolivia, by M. Sacc. An analysis of this vast deposit, which is large enough to supply the whole of the world with nitrate of potash, yields the following results:—Nitrate of potash, 60.70; borax, with traces of salt and water, 30.70; organic substances, 8.60; total, 100.00. The author concludes that the saltpetre is the result of the decomposition of an enormous deposit of fossil animal remains.

THE BASIC OPEN-HEARTH STEEL PROCESS.

By THOMAS GILLOTT, M. I. C. E.

From the Selected Papers of the Proceedings of the Institution of Civil Engineers.

In the following account of the application of the basic, or Thomas-Gilchrist, dephosphorization process to the open-hearth furnace, the author has confined himself to his own personal experience, dating from May, 1882, at the works of the Farnley Iron Company, near Leeds. The basic Bessemer process is now well known and established, and will probably be the most extensively adopted for the production of steel in large quantities for general use; but, as in the contemporary acid processes the Siemens furnace retains advantages for the production of exceptional qualities, and has the further capability of dealing with raw materials which are altogether unsuited for the Bessemer (basic) process. Pig-iron most suitable for the basic Bessemer process should approximately contain, according to Messrs. Thomas and Gilchrist, silicon, 0.5 to 1.8; phosphorus, 0.8 to 3; sulphur, under 0.3; manganese, not over 2.5 per cent.; and, in order to secure the necessary heat, the carbon would probably have to be 3.5 per cent.; but in the basic open-hearth process the proportion of heat-producing elements need not be high, and large quantities of wrought iron scraps, which often contain 0.2 per cent. of phosphorus, and are altogether unsuited for the acid process, may be converted into steel of high quality and great purity. After unsuccessful attempts to produce a high-class steel in the acid process by the use of hematite pig for the bath, and wrought-iron scraps, or specially puddled iron made from pigs in which phosphorus was comparatively high, the author was instructed to apply to the open-hearth furnace the process which Messrs. Thomas and Gilchrist had at that time just succeeded with in the Bessemer converter. As no basic bricks excepting such as were too costly for practical use, were suitable for constructing the furnace throughout, the author consulted chemists as to materials which would be sufficiently refractory at a steel-melting heat, and at the same time securely isolate the dolomitic lime basin of the furnace from the silica walls above; so as to prevent that fluxing of lime and silica, and consequent destruction of the furnace, which would result from these materials being in immediate contact. He was advised that magnesia on the lime, alumina above the magnesia, and silica brickwork carried up on the alumina, would be secure; so, after some trials, bricks were made from magnesite, containing 98 per cent. of carbonate of magnesia, and others from bauxite of the approximate composition, silica, 15; alumina, 82; lime, 1; peroxide of iron, 2; and with these the furnace was built. This furnace had been previously used in the acid process for 50 to 55 cwt. charges, and was altered to suit the basic process. At the commencement the author recognized the necessity of providing for the removal of the slags in the early stages of the process, so that the banks of the furnace might be preserved; and any phosphorus transferred from the melted portion of the charge to the slags could be withdrawn, so as to reduce the amount of purification at the later stages, and allow the heat to be better employed by reducing the covering of slag on the metal; and this provision has proved very useful. The building of the furnace was conducted as follows: The iron bottom plates and the bridge plates are similar to those used for the acid furnace; brackets bolted to the side plates of the furnace support the brickwork by a plate at the level of the top of the lime basin, and prevent settlement of the upper brickwork in case of any shrinking of the lime basin or fluxing in work. The metal tapping hole and spout are at one level, and two slag tap holes at higher levels on the opposite or charging side of the furnace. In other respects the furnace does not differ from an ordinary Siemens furnace. Bricks made from magnesian lime, and of the following approximate composition—lime, 58; magnesia, 24; silica, 8; alumina and oxide of iron, 10 parts—are burnt at a full white heat, crushed, mixed with hot tar,

in a mortar mill, and are taken immediately to the furnace and rammed with red hot rammers over the furnace bottom plates, wooden plugs being inserted to form the tap holes, parts of the bottom being walled in the same bricks, and grouted with material similar to the ramming. Isolating courses of magnesia and bauxite bricks are laid on the top of the iron brackets on the sides, and across the ends of the basin over the bridge plates; and the shape of the hearth is completed by lime ramming. The use of hot rammers is necessary to coke the tar; otherwise the lime swells and falls to pieces in about twenty-four hours after mixing. The upper part of the furnace is then completed in silica brick in the usual manner, the gas and air passages, regenerators, reversing valves, &c., being similar to those used in making steel in the (acid) Siemens-Martin process.

The building of the furnace having been completed, and the furnace lighted, it will be sufficiently hot in about seventy-two hours for forming the bottom, and for this a full melting heat is necessary. Well burnt and freshly ground magnesian limestone is laid over the bottom and up the sides, with not more than 10 per cent. of ground firebrick added, so as to just flux the lining sufficient for binding the layer forming the furnace bottom. The wooden plugs for forming the tap-holes are burnt out, and the holes are stopped by dry lime only, or dry lime mixed with a small quantity of powdered coke. The gas and air ports should be so arranged as to throw the flame well down on the bottom, so that the heat may be sufficient to allow of the smallest possible admixture of silicious flux. The furnace is then ready, and the operation is thus conducted: Fresh and well-burnt lime (that used was from stone containing 98 per cent. of carbonate of lime), about one-twentieth to one-tenth of the weight of the pig-iron, is laid upon the bottom of the furnace; the pig is then charged, and the wrought-iron or steel scraps are put on the top of the pig, all being cold. The whole of the charge, if possible, is placed in the furnace at the commencement; feeding afterwards is always avoided when the state of the furnace will admit. In three or four hours, the pig being melted, the charge will have sunk so as to enable some slag to be tapped off. The first slag is generally very fluid, and more or less so as the silicon in the pig is higher or lower; consequently the sides of the hearth are far better preserved by getting rid of the more silicious slag at an early stage, and before the full heat is reached. In three and a-half to six hours, the time being dependent on the proportion of pig to scrap, the whole charge will be melted, more slag can be taken off if required, some lime added if the slag is very fluid, and ore with the lime if the proportion of pig to scrap is high. When boiling has ceased, and after the bath of fluid metal has been well stirred, the metal may be sampled. The samples are taken from the furnace in a ladle, cast into an ingot about 3 inches in diameter by 2 or $2\frac{1}{2}$ inches thick, and flattened, when sufficiently cool, under a steam hammer into a plate $\frac{3}{4}$ inch thick. This is quenched in cold water and then bent double, broken in two pieces, and the larger portion broken again. When the metal is sufficiently pure, these samples are so tough as to be scarcely, but nearly, broken through by being flattened close; the fracture is generally free from crystals, of good color, and uniform. Crystals in specks are sometimes found, but when regular as regards size, and equiangular to the naked eye as regards shape, the presence of crystals does not always indicate less purity than does their absence. Long streaks in the fracture, dark color, with little toughness, are more certain indications of the presence of phosphorus. The sample being satisfactory, the slag may be removed; but at this period it is generally too pasty to run, therefore it is withdrawn by raking through the center door, which is placed $4\frac{1}{2}$ inches lower than the two end doors. About 5 per cent. of hematite pig is then charged through the end doors on the bridges, which pig when melted causes the metal in the bath to boil more or less violently for about fifteen minutes. After this, fifteen to thirty minutes are allowed to elapse, and any excess of slag beyond what is required to cover the metal in the casting ladle is removed, when the metal in the bath is ready for adding spiegel or ferro-manganese, and tapping. The addition of hematite pig causes a thorough agitation of the bath far beyond what can be done

by stirring with an iron bar; and every analysis the author has had made proves a further removal of phosphorus by the addition. There is a drawback, however, to this on account of the occasional failure of parts of the basin during the after-boil, which causes a further boiling out of the bottom or sides of the basin in the neighborhood of the failing place. Sometimes the tap-hole stopping commences to work out during the after-boil; and these accidents are generally due to some of the lime used for repairs, or stoppings, being imperfectly burnt; or it has been partially slaked during, or after grinding. The author has tried several times to secure the quality of steel aimed at without adding pig at the end of the purification, but the results have been uncertain and irregular. In only one instance has the author obtained evidence of re-phosphorization on adding the ferro-manganese after adding hematite pig. In this case the sample that had been flattened, quenched, and broken, tested 0.104 per cent., and the sample from the finished steel showed 0.122 per cent. of phosphorus. In other cases where the two respective samples were tested for phosphorus, the reduction per cent. averaged 0.016, and varied from 0.008 to 0.025 less phosphorus than the trial samples contained. When quite satisfactory the trial samples show 0.06 to 0.07 per cent. of phosphorus.

The author has always added the ferro-manganese in the furnace, as the reaction is somewhat too violent to permit of addition being made in the casting-ladle after the metal has been tapped; and a more uniform mixture is secured by adding in the furnace. A small quantity of slag is usually left on the metal so as to cover the steel in the ladle and avoid chilling while pouring the ingots. Some of this slag is nearly always left on the furnace bottom, and is raked out at the door, and some also remains in the tapping hole. If the slag be not removed immediately, the clearing of the tap hole is a troublesome operation, and for this purpose a door opposite to the tap hole is absolutely necessary. After casting the metal and raking out the slag, the bottom and sides of the furnace basin are repaired by magnesian lime, well burnt and finely ground, and any holes that may have been formed during working are carefully filled with the same kind of material. The gas is turned on to fix the lime by semi-fusion with the surface of the basin, the tap hole is stopped, and the furnace is ready for another charge in from one hour to three hours after the cast is over. The slag adhering to the bottom of the furnace requires occasional removal by melting off with fluxes, or breaking away; otherwise the capacity of the furnace is reduced and the level of the metal unduly raised. The quality of metal which the Farnley Iron Company desired to produce was that which possessed the maximum ductility when cold, together with the capability of sustaining, without failure or injury, the severe tests required by the most difficult flanging and welding when hot. In this respect the results of the mechanical tests which will be submitted are a sufficient proof of success; the chemical features will be dealt with separately. But it may here be remarked that Farnley Best Yorkshire cold-blast pig-iron has been the only phosphoric pig-iron used; and, being so low in silicon and sulphur, regular in quality, and more free from sand adhering to the pig than the cheaper hot-blast irons, a large portion of the successful results obtained must be credited to the principal raw material used. Two typical casts will now be given (229), one in which pig with a small admixture of wrought-iron scraps was worked with ore; and another (375) with less pig, more scrap, and no ore:

	Tons.	cwt.	qr.	lb.
No. 229. Charge 6.30 A.M.				
Farney No. 3 pig..	1	8	0	0
June 29, 1882.				
Charge 6.30 A.M. Steel Scrap.	0	8	2	0
Charge 2.45 P.M.				
Hematite pig No. 3.	0	2	0	0
Charge 3.10 P.M.				
Spiegel, 18 per cent. Mn.	0	1	1	0
Charge 3.25 P.M.				
Ferro-Mn., 53 per cent.	0	0	1	5
	2	0	0	5

Commenced adding ore and lime at 10.30 A. M., 4½ cwt. Sommorostro ore, and 1¾ cwt. burnt lime; 2 cwt. of slag run off 2.40 P. M. Sample flattened, quenched, broke tough, without any crystal in fracture, 3½ cwt. of slag removed. Cast 3.28 P. M. One 15 inches square, and one 12 inches square, full ingots.

12-inch ingot hammered into a slab and rolled into a plate $8.10 \times 5.4\frac{1}{2} \times \frac{1}{2}$ inch bare. Strips from plate heated red, quenched, bent cold, and closed to $\frac{3}{8}$ inch between folds without crack. The plate, after annealing, was bent to 2 feet 9 inches diameter, welded longitudinally, and flanged at both ends without crack or failure.

[Tests and analysis are given afterwards.]

	Tons.	cwt.	qr.	lb.
No. 375. Charge 6.30 A.M. Farnley No. 3 pig.	0	17	0	0
Charge 6.30 A.M. Common wrought-iron scrap.	0	6	0	0
Charge 6.30 A.M. Wrought turnings.	1	2	0	0
Charge 1.20 A.M. Hematite No. 3.	0	2	0	0
Charge 1.20 A.M. Ferro-manganese, 71 per cent	0	0	2	19
	2	7	2	19

Four cwt. of slag taken off, and about $1\frac{1}{2}$ cwt. left on metal, 1.10 P. M. Sample flattened, quenched, broke very tough, no crystals in fracture.

Cast 2.25 P.M.,	Ton.	cwt.	qr.	lb.
1 ingot, 19 inches square..	1	17	0	26
1 piece, 12 inches square.	0	5	2	14

Hot and cold tests satisfactory. Phosphorus in finished steel=0.056 per cent.

The design of the furnace in several respects unsatisfactory for basic work. When lime is added during the melting, small quantities carried by the draught on the faces of the silica bricks forming the ports, rapidly flux the gas and air passages, which causes a silicious liquid to trickle down across the furnace, and a further fluxing of the lime basin on the top of the bridge-plates B is occasioned by the droppings from the faces of the ports. The author has not yet succeeded in making a lime brick that will withstand the current of gas and air, and the cooling down of the furnace after tapping. Under the combined effects, disintegration of the lime brick occurs, and any failure of the ports must be repaired at once—for which the furnace has to be cooled down. Usually the ports need repair after eighteen to twenty-one days' work; the side wall on the tapping side lasts about twice as long as the ports, and the crown of the furnace in the center requires minor repairs at the same time as the sidewalls. Showers of minute sparks, with brown smoke at the chimney top, are given off in the later stages of the process, and the regenerators require cleaning out after sixty or seventy casts. The slag tap holes in the furnace used are too near the jambs between the charging doors, but from the arrangement of the furnace no other position could be found for them. To remedy these inconveniences, the author has designed another furnace, in which the gas and air passages are carried up outside the hearth and in separate casings, so that they may be changed and the inlets repaired without cooling down the furnace. This arrangement of gas and air ports has been patented by Messrs. Hackney & Wailes. Three doors for charging and repairing, and two slag-spouts are provided on the opposite side to the tap hole for the metal, and two sight holes for inspecting the furnace while working. The other reference letters apply to the same parts as the furnace before described. Owing to the very soft quality of steel produced the heat required is nearly as great as Sheffield silica bricks are able to withstand; so long as the slag can be kept clear of the magnesia and bauxite bricks they have been satisfactory, and, but for their great cost, magnesia bricks would doubtless be much better than silica bricks for faces of the ports. The waste is not excessive; taking the more recent work, without charging or crediting skulls and pit-scrap, the results are as under:

CASTS 302 TO 408 (inclusive).

Materials Charged.

	Tons.	cwt.	qr.	lb.
Farnley pig-iron.....	90	8	0	0
Hematite pig-iron.....	9	13	2	0
Iron and steel scrap	130	5	0	16
Ferro-manganese.....	4	14	2	14
	235	1	1	2

The total weight, including spare metal, of ingots produced from the above is 219 tons 6 cwt. 3 qrs. 26 lbs., or about 93 per cent. of the raw materials. About 9 cwt. of raw dolomite per ton of ingots has been used for the repairs of the furnace, as deduced from the work done during one year. The following mechanical tests are from casts of the numbers annexed; nearly all the plates have been for boiler-works requiring difficult flanging; excluding some three or four accidental casts, they are a fair average of the quality of steel:

Breaki'g Weight per Square Inch.	Elongation in Inches.			Reduction of Area.	Description of Piece Tested.
	10	8	2		
Tons.	Per cent.	Per cent.	Per cent.	Per cent.	
25.89	25.00	27.50	53.12	55.75	No. 229 plate from ingot 12 inches square; size, 2.015 inches by 0.46 inch.
22.29	31.25	34.06	53.12	62.90	No. 242. Axle from 15 inches square ingot; billet turned to 1 inch diameter.
24 96	35.00	37.50	62.50	62.73	No. 245. Plate from 12 inches square ingot; size, 2.03 inches by 0.37 inch.
23.00	30.00	31.25	62.50	63.48	No. 246. Plate from 15 inches square ingot; 1.99 inch by 0.755 inch.
24.16	27.50	30.47	—	56.53	No. 289. Plate from 15 inches square ingot; size, 2.035 inches by 0.59 inch.
23.92	28.12	34.18	59.37	58.25	No. 304. Plate from 19 inches square ingot; size, 1.52 inch by 0.68 inch.
25.98	24.37	26.56	40.62	50.00	No. 305. Billet from axle from 19 inches square ingot, turned to 1 inch diameter.
26.68	23.75	25.00	43.75	49.64	No. 313. Plate from 19 inches square ingot; size tested, 1.765 inch by 0.69 inch.
26 68	26.25	28.47	53.12	49.77	No. 315. Plate from 2 feet 3 inches by 1 foot ingot; size tested, 1.52 inch by 0.705 inch.
24.07	28.75	31.25	50.00	48.93	No. 345. Plate from 19 inches square ingot; size tested, 2 inches by 0.565 inch.
24.76	27.99	30.62	53.12	55.49	Average.

All the test pieces were parallel for a length of 11 inches, plates being machined on the edges only; a space of 10 inches long was in every case divided into ten equal parts. The cases in which a length of two inches adjacent to the fracture showed a greater elongation per cent. than the contraction of area per cent., are explained by the concave shape of the ruptured edges, so that when the pieces were joined for measuring the elongation, the fractured edges were in contact at the sides only; and the true elongation is consequently less than the distance between the points from which the percentages in the table are calculated; this only occurs with rectangular sections.

The pig-irons used were of the following composition:

Analyses by J. O. Arnold, F.C.S., Ironmaker.

	Farnley.	Hematite.
Iron.....	93.111 (by difference)	93.194
Graphite.....	3.250	3.798
Combi'd carbon	0.392	0.410
Silicon	1.245	2.285
Sulphur.....	0 013	0.004
Phosphorus....	0.601	0.058
Manganese.....	1.188	0.199
Titanium.. ...	—	0.152
	100.000	100.000

The wrought-iron scraps used were not all of high quality, and would average not less than 0.2 per cent. of phosphorus; consequently, charges 229 and 375, before given, would respectively contain 0.46 and 0.35 per cent. of phosphorus at the commencement, the samples taken from the casting ladle in both cases showing that the phosphorus had been reduced to 0.067 and 0.056 per cent. respectively. Other phosphorus tests from casts for which the charges were similar to 375, the selection being made from a number, are as follow:

Casts, No.	242	271	273		
P. per cent.	0.065	0.078	0.090		
	274	275	276	283	
	0.097	0.092	0.086	0.097	
Casts, No.	287	300	301	305	
P. per cent.	0.076	0.083	0.082	0.050	
	335	336	340	348	351
	0.083	0.076	0.064	0.079	0.053
Casts, No.	352	360			
P. per cent.	0.060	0.071			
	375	382	383	402	
	0.056	0.055	0.056	0.062	

All the foregoing phosphorus tests were from ladle samples taken after tapping, except No. 305, which was drilled from a finished forging; some of those given are of casts where the phosphorus was expected to be somewhat high. The author is indebted to Mr. J. O. Arnold, F. C. S., for all the analyses of metal and slags, excepting that of the hematite pig. As in three samples of Farnley pig-iron sent to other chemists the phosphorus was respectively returned as 0.38, 0.317, and 0.29 per cent., and also as the percentage of phosphorus in the finished steel appears high compared with the published results of bassic Bessemer work, the author requested Mr. Arnold to furnish him with an account of the method by which the phosphorus was estimated, and his note is given in an appendix to this communication. The order of removal of phosphorus is evidently different from that which it has been shown to be in the Bessemer converter. In the latter process it has been proved that the phosphorus is not eliminated to any great extent until the carbon and silicon have almost disappeared; consequently the author was scarcely prepared to find so small an amount as 1.974 per cent. of phosphoric acid in the final slags of charge No. 229. He therefore took a sample of slag from No. 301, which had been run off after the pig was fluid, but before the scraps were melted, and this sample, when tested, afforded 5.087 per cent. of phosphoric acid. Athough samples of metal have been taken when the whole charge was melted, and before boiling commenced, the phosphorus in the melted metal was always found to be much lower than the charge was known to contain originally, proving that the elimination of phosphorus in the basic open-hearth process commences in the early stages. With respect to the removal of sulphur, the results were not so encouraging. The preceding table gives three tests: (*a*) when the charge was all melted; (*b*) from the flattened test sample; and (*c*) from the finished steel. They were taken from casts in which scraps known to be high in sulphur were purposely tried.

None of these charges were satisfactory under the hot tests. The evolution of sparks and brown smoke has been before referred to, and as the author in several instances was unable to balance the phosphorus in the charge with that contained in the slags added to the phosphorus left in the finished steel, he took samples of the deposits in the regenerators. One sample from the gas regenerator contained 4.741 per cent., and another sample from the air regenerator gave 2.995 per cent. of phosphoric acid (P_2O_5), the other constituents being SiO_2, Fe_2O_3, CaO, and MnO. These deposits appear to indicate that some of the phosphorus leaves the furnace otherwise than with the slags. Three analyses of finished steel are furnished from charges that have been already given in detail; one sample (229) was taken by a sample spoon from the casting ladle, but the other two, Nos. 245 and 345, both similar charges were drilled from the specimens tested in the machine, the tensile strengths, &c., of which are included in the table of tests:

No. of Cast.	Sulphur.			Phosphorus.		
	Per cent. *a*	Per cent. *b*	Per cent. *c*	Per cent. *a*	Per cent. *b*	Per cent. *c*
213	0.226	0.192	0.218	0.114	0.066	0.070
214	0.230	0.182	0.172	—	0.039	0.041
225	0.200	—	0.189	—	—	—
227	—	—	0.107	—	—	—

	No. 229.	No. 245.	No. 345.
	Per cent.	Per cent.	Per cent.
Carbon.....	0.240	0 140	0.140
Silicon.....	trace	trace	0.004
Sulphur.....	0.060	0.037	0.074
Phosphorus..	0.067	0.056	0.050
Manganese..	0.526	0.191	0.598

A quantity of slags from pig and scrap charges similar to Nos. 245 and 345, all being taken from those run off before the final additions and ground up, gave an analysis SiO_2 17.830, and P_2O_5 2.726 per cent.; and a complete analysis of slags tapped out of the furnace with the metal, and consequently taken after the additions of hematite pig and ferro-manganese, is given on following page.

	Per cent.		Per cent.
P_2O_5	0.806	CaO	39.700
S_1O_2	13.640	MgO	11.750
Fe_2O_3	1.370	MnO	8.762
FeO	18.571	S.	0 119
Al_2O_3	2.235	Alkalies and loss	3.047
			100 000

The author has purposely omitted the question of cost, but it may be stated that the process is more expensive as regards furnace repairs, and greater attention is required in working, although the number of men employed at the furnace is not greater than required by the acid process. The preparation of the material for repairs, namely calcining and grinding dolomite, and burning limestone for adding, is not a part of the duties of the melters, and involves greater expenses than those for corresponding work in the Siemens or Siemens-Martin processes. For the production of exceptionally soft steel of great purity, and the utilization of much wrought-iron scrap and certain kinds of phosphoric pig that in the present acid processes are useless for good steel, the basic open-hearth process offers peculiar advantages, and will doubtless be further developed in the future.

ON PERSONAL SAFETY WITH ELECTRIC CURRENTS.

By Prof. A. E. DOLBEAR.

From "The Engineer."

The serious accidents which have occurred within the past four or five years through accidental contacts with wires carrying strong electric currents have seemed to call attention to the necessity of providing safeguards against such mishaps. It is probable that carelessness has been the cause of most of the accidents reported, and it is true that if weak currents only were used nobody could be hurt. It is, however, worth while to consider the electrical relations of the human body in order to learn where danger lies. I have noted in various places the opinions of different persons as to what constituted a safe current. In one of the old books it is stated "a spark 18in. long begins to be dangerous." In another place one says that a difference of potential of 800 volts is too high an electro-motive force for individual safety.

Now a difference of potential of 1,000 volts will not give a jumping spark the hundredth of an inch long. The electro-motive force developed by the Holtz electro machine may be as high as 50,000 volts, and the spark from it will at most give a spasmodic jerk to the elbow and no manner of hurt come of it or of repeated shocks from it, so that more than difference of potential must be considered in determining what is dangerous about electricity. The ability of electricity to do work of any kind, destructive physiological work as well as any other, depends upon both difference of potential and current strength, and the amount of work is proportional to the time also. Now the discharge from a Holtz machine through a short wire may give a very strong current; for example, let E=50,000 volts, R=.001 ohm, then $\frac{50{,}000}{.001} = 50{,}000{,}000$—fifty millions of amperes; but the wire may show no sign of being injured, for the time of the current's passage was too short, probably less than the millionth of a second. If the discharge had continued for an appreciable part of a second the wire would have been vaporized. The discharge is probably equally quick when taken on the knuckles, but there is not enough energy to hurt anything. Again, the amount that will traverse any conductor, with a given difference of potential between its ends, will vary inversely as its resistance, and for the human body it may only roughly be calculated. The resistance of the body is very great. Many measurements, made with different individuals taking wires in their fingers and hands, gives a resistance varying between 6,000 and 15,000 ohms; but this depends in a large degree upon the moisture of the skin when contact is made. Hands which are ordinarily dry have a high resistance;

the same hands moist with perspiration or purposely wetted may lose half their resistance. Dr. Stone, of London, has made many experiments, and finds that the resistance of the body may be reduced to 500 ohms or less, by having the skin soaked.

On an arc light circuit with forty lamps the difference of potentials will be about 2,000 volts. If a man with a dry, thick skin were to grasp the terminals at the dynamo, the current that would go through him would be $\frac{2000}{10000} = .2$ of an ampere, and in one second two-tenths of a coulomb would have traversed his arms. If the same hands were soaked, the current might be $\frac{2000}{500} = 4$ amperes, or 4 coulombs per second. In the first case there would have been spent in him an amount of energy equal to $2000 \times .2 = 400$ watts, or more than half a horse-power, and in the second case $2000 \times 4 = 8000$ watts, or $\frac{8000}{746} = 10$ horse-power in the interval of one second. Now, any electromotive force above about 1.5 volts is sufficient to decompose water, and it has been shown that the fluids of the body are better conductors of electricity than any of the tissue, even the nerves; it may fairly be inferred that such a current with such an electro-motive force might decompose a notable quantity of the fluids of the body into their constituent gases.

To determine the highest limit of safety would require experiments which no human beings would be willing to submit to. Animals might be employed perhaps; but if 800 volts have at any time proved to be dangerous, one may set a lower limit to the resistance of the body and determine the current strength $\frac{800}{1000} = .8$ amperes. That result looks threateningly large, but it is because the resistance is made so low. I have never found one less than 5.000 ohms, then $\frac{800}{5000} = .16$ amperes. But that represents 128 watts—a quantity of energy no one would care to have spent in him. After all, what would be safe for one would be entirely unsafe for another; so that each individual would have his own factor of safety, or the difference of potential which he could work with, with impunity. From what we now know it would seem as if one-tenth of an ampere current body was as much as any one could safely have traverse his body for one second. If, then, he fixes his minimum resistance, the product of the two will give him the electro-motive force which he may feel timidly safe with. Thus, if one's resistance with wet hands is found to be 8,000 ohms, then $8{,}000 \times .1 = 800$ volts; while if his resistance was only 1,000 ohms, he could only venture to touch wires having a difference of potential of $1{,}000 \times .1 = 100$ volts. The ordinary incandescent light circuit would be on his limit.

THE EMPLOYMENT OF DOUBLE FLOATS FOR MEASURING VELOCITIES IN LARGE STREAMS.

By H. BAZIN.

Translated from "Annales des Ponts et Chaussées," for Abstracts of the Institution of Civil Engineers.

A comparison is made in this article of recent important and careful observations of the velocities of flow in large streams, with the object of showing that the discrepancies between the results are merely apparent and due to the nature of the instruments, and with the view of indicating the corrections necessary in the results of observations with double floats.

The current-meter, with an electric recorder, is the most reliable instrument; but if the experiments are conducted in a deep rapid current, the apparatus must be costly. The double float provides a simple and ready method, but it is liable to errors, which increase so much with the depth and velocity of the current as to render the results useless in some cases. The conditions necessary to ensure perfect accuracy are, that the two floats should travel with the same speed as the layer of water surrounding the bottom float, and that this float should retain its original position in the stream. Unfortunately, the surface float and cord modify the motion of the lower float, and

the lower float is raised by the eddies of a rapid current; and when the velocity exceeds 5 feet a second no reliance can be placed on the position of the bottom float.

The experiments compared are those of Mr. Ellis on the Connecticut, 1874, with a current-meter and floats; those of Major Allan Cunningham on the Ganges Canal, in 1874-79, with floats; those of Mr. Harlacher on the Elbe and the Danube, in 1876-79, with a current-meter; those of Messrs. Nazzani and Zucchelli on the Tiber, in 1880-81, with a current-meter and floats; and those of Mr. Gordon on the Irrawaddi, in 1882, with a current-meter and floats. Numerous Tables are given of the results of each series of experiments.

In Mr. Ellis's experiments the velocity of the stream was small, the greatest velocity hardly exceeding 3¼ feet per second; whilst the area of surface of the top float and connecting cord was only one-sixth of that of the bottom float, so that the bottom float was not liable to be affected by eddies, and could be little influenced by the motion of the cord and top float. Accordingly, as might be anticipated, the results of the two methods of observation fairly coincide. The surface-velocities obtained by the current-meter are evidently too low, owing doubtless, either to the ripples over the surface of the water, or the eddies produced by the boat from which the current-meter experiments are taken. On the other hand, the velocities given by the double float are manifestly too great for the lower depths. As in these experiments the velocities are very low, the slightest errors modify the results; so that the parabola, indicating the decrease in velocity in a vertical plane in a line with the current, cannot be traced with precision. The proportion of the surfaces of the upper float and connecting cord to the surface of the lower float was a little over one-half in Major Cunningham's experiments; and the velocity of the current was greater than in Mr. Ellis's observations. The increased relative proportion of the surface of the upper float and cord, and the increase in velocity, together with the fact that Mr. Ellis's observations were conducted on a river and the others on a uniform canal, materially reduce the proportion between the maximum and mean velocities, and the parameter of the parabola marking the decrease in velocity. In Mr. Harlacher's experiments the value of the relation between the maximum and mean velocities is larger than that obtained by Major Cunningham, the maximum velocity of the streams being also larger. The maximum velocity was almost always at the surface in the Elbe observations, taken at Tetschen; and the parameter reached, on the average, the value of 0.61, which is higher than in the previous observations. The upper float and cord in Mr. Zurchelli's observations on the Tiber exposed a surface of nearly one-fifth of that of the lower float, in depths ranging between 20 and 23 feet, and about two-fifths when the river had risen so as to attain depths of 33 to 50 feet. In every case, in these experiments, the relation of the velocities observed at the various points to the mean velocity approximated to unity, the values diminishing with the height of the river for points near the surface, but increasing for points near the bottom. Comparing the above results with those on the Mississippi and the Irrawaddi, it appears that in these rivers the relation of velocity to mean velocity, and the parameter also, decrease in proportion as the depth increases, but are smaller, especially on the Mississippi. This progressive decrease is due to the influence of the surface of the connecting cord, which increases with the depth, and ends by completely vitiating the results in the great depths of 70 feet and 110 feet reached by the Irrawaddi and Mississippi respectively; for the relation of the surfaces of the upper float and cord to the surfaces of the bottom float, whose maximum on the Tiber is two-fifths, attains four-fifths on the Irrawaddi, and unity on the Mississippi. The results obtained by Mr. Nazzani with current-meters on the Tiber do not coincide with those from the double floats, as the relation of the velocities and the parameter increase in the experiments with the current-meter and decrease with the floats. In Mr. Gordon's recent comparative experiments on the Irrawaddi with current-meters and floats, the results obtained are very different. The proportion between the velocities observed at the various points and the maximum velocity decreases with the depth in both cases, but the decrease is much more marked in the results obtained by the current-meter; and in

some instances the results of the two methods at the greatest depths differ by one-third of the maximum velocity. Mr. Gordon's observations prove beyond a doubt that the employment of double floats for measuring velocities, at considerable depths in rapid currents, leads to serious errors. On the other hand, these experiments also indicate, as in previous results, that the current-meter furnishes too low velocities at the surface.

Comparing the results of the preceding experiments, it appears that the relation between the velocities varies but little in the observations with current-meters, being always between 1.14 and 1.20; whilst this relation in the case of floats is lower and more variable, ranging between 1.02 and 1.14. The influence of the cord connecting the two floats is more marked as the depth and velocity increase. It is evident that gaugings conducted with double floats furnish too large values for the discharge, and should be revised; whilst the unexpected rise of the proportion between the maximum and mean velocity on several large rivers necessarily implies a greater impediment to the flow, so that the formula ordinarily employed would also give too large discharges. The old formulas of Prony, Eytelwein, and others, were based upon a limited number of observations, representing simply the steady flow of a moderate sized river for which the formula $v=50\sqrt{\mathrm{R\,I}}$ was generally adequate. The observations on the Seine and Saône show that for these gently flowing rivers the value of the coefficient c may be made 50, as in the above formula. Mr. Graëff has found $c=36$ to be suitable for the tributaries of the upper Seine. It appears that for the Rhine at Basel, in spite of the size of the river, the value of c is as low as 38, owing to roughness of the bed, which is covered with large shingle. Even very large rivers are affected by the irregularities of their bed, so that for the Danube at Vienna $c=42$. In the Irrawaddi also, the value of b is less than 50. The Mississippi experiments give anomalous results, and very high values for c where the inclination is very small; but taking only the most reliable results, the mean value of c would be 70. These observations, however, like those on the Irrawaddi require correction, which would reduce the value of c below 60. Observations with current-meters are needed on the very large rivers, from which a suitable coefficient might be deduced, so that serious errors in the calculation of their discharges may be avoided, for which at present there are not sufficiently accurate data.

THE TRANSMISSION OF POWER BY ELECTRICITY.

By ROBERT LUCE, A. M.

Contributed to VAN NOSTRAND'S ENGINEERING MAGAZINE.

THE advantages to be gained from an economical method of transmitting power are self-evident. Many systems have been tried and found wanting. Endless ropes and chains are too cumbrous and expensive. Waterpipes are liable to all sorts of catastrophes, and water-power from artificial reservoirs is both costly and inefficient. Gas motors are of limited power, and compressed air is hard to manage. But in electricity, thanks to living inventors, we have a force into which power can be transferred as by the wave of the magician's wand, a force which flows to any distance with the rapidity of lightning and the stillness of a ray of sunlight, and then at bidding resumes its original shape quicker than thought can follow it. This force has been known to the world for ages, but it is only within the past decade that its vast possibilities have taken definite shape in the mind of science. The electric transmission of power is yet in its childhood, but its growth has been so wonderful that the world has not been able to keep up with it. Words written about it a year ago are now behind the times. Young as it is, the science of dynamical electricity has already become of such world-wide importance that its history, present condition, and possible future are of general interest.

The keystone of modern science is the

truth that matter and energy, the components of the universe, are never destroyed. To put the converse of half of this truth into scientific parlance, energy is always conserved. It may change its form or its place, but it never increases or diminishes, never grows, never shrinks. Energy may be active, or it may be dormant,—in scientific phrase, potential. The great problem which confronts mankind to-day—which always has confronted, always will confront the human race—the problem of problems in the physical world is, how to utilize to the best advantage the energy dormant in matter? How shall we get the most work out of coal, wood, water, air, and every other form in which matter presents itself to us? Energy is seldom in the place we want it, almost never in the form we want it. We must carry it to the desired place in its original bonds, as, for example, in coal, or we must transform it and carry it in some new prison, as, for example, in coal gas. The question is, how can we transport energy so as to lose the least of it while performing the least labor? Students of dynamical electricity maintain to-day that they have solved the problem. They maintain that energy can be transmitted by electricity more cheaply, with less net loss than in any other way known to modern science. The claim is surely worth investigating.

To discuss intelligently the methods by which energy, alias power, is usually transformed into electricity, it will be necessary to go back to the beginnings of electrical science. And yet it is not so very far back, for it was but a little over a century ago that the science was in so rude a state that the Electoral Academy of Bavaria actually proposed the following subject for a prize dissertation: "Is there a real and physical analogy between electric and magnetic forces, and if such analogy exists, in what manner do these forces act upon the human body?" At that time physicists were divided as to the correct answer to the question at issue, and for 45 years they quarreled over it, until at last Oersted settled it forever by demonstrating the magnetic properties of electric currents. In 1829 this Danish physicist noticed that a magnetized needle was deflected from its direction when it was placed near a closed electric circuit. The same phenomenon occurring when the current was replaced by a magnet, it became evident to him as to all contemporary physicists that a complete analogy existed between electricity and magnetism. From this first observation really dates one of the most beautiful achievements of the human mind in the domain of natural philosophy. Before 1820 the intimate relation between the electric current and a magnet had often been spoken of, and had even served as a basis for several electrical theories; but no one had rendered it palpably evident until Oersted's experiment opened to science the luminous path which scientific men have since trod with so much success. It was in 1820 that Ampere made known to the world the mutual action of two currents, and of magnets on currents; and in the same year Arago discovered that an electric current imparts magnetic properties to iron and steel. Ten years later (1830) Faraday supplemented the labors of Oersted, Ampere and Arago, by demonstrating that a magnet can create an electric current.

From the discoveries of these four men has been developed the science of dynamical electricity. Just as geometry was constructed from axioms, self-evident truths, so this science has been built up from certain truths which may be termed electrical axioms, and it cannot be too forcibly impressed upon the reader's mind that these electrical axioms must be thoroughly understood, with all their significance and in all their bearings, before proceeding further. They are known from the name of their formulator as Ampere's laws, and are:

I. Two currents which are parallel and in the same direction attract one another. (A).

II. Two currents parallel, but in contrary directions, repel one another. (B).

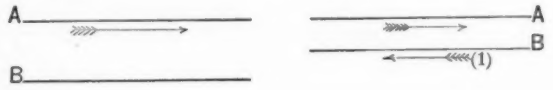
From these we deduce two more laws, which can easily be verified by experiment:

III. Two rectilinear currents, the directions of which form an angle with each other, attract one another when both approach or both recede from the apex of the angle. (C and D).

IV. They repel one another if one approaches and the other recedes from the apex of the angle. (E).

To continue our mathematical simile: In geometry, every proposition has its converse. Likewise the laws of parallel and angular currents have their converse in what is known as Lenz's law, which is:

"If the relative position of two conductors A and B be changed, of which A is traversed by a current, a current is induced in B, in such a direction that by its electro-dynamic action on the current in A it would have imparted to the conductors a motion of the contrary kind to that by which the inducing action was produced."



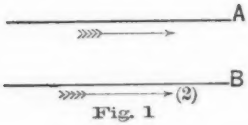


Fig. 1

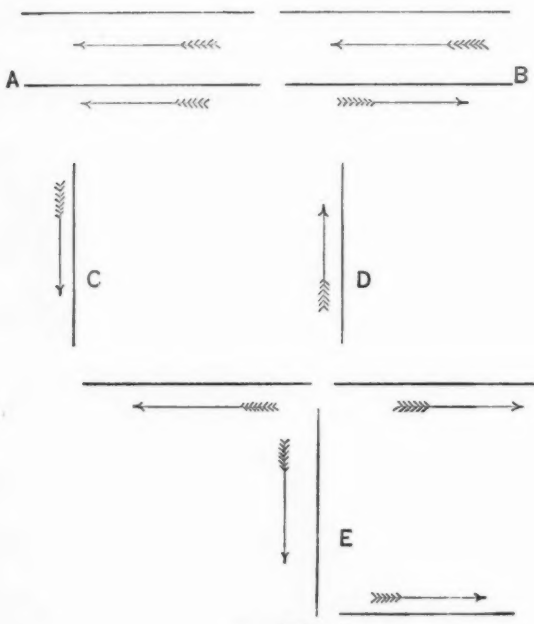


Fig. 2

In Fig. 2 suppose the conductor A be traversed by a current, but the conductor B not so traversed. If we cause B to approach A, a current will be induced in B in the direction of the arrow (I), for a current flowing in that direction in B would, according to Ampere's second law, tend to repel itself from the current flowing in A, and there would be a motion of the contrary kind to that by which the inducing action was produced. From this it is easy to see how motion will produce currents of electricity, and, *vice versa*, how currents of electricity will produce motion. The elaborate dy-

namo-electric machines of to-day are worked on these very principles according as they are used respectively as generators or motors. Strange to say, nearly half a century passed before any one thought of what they had in common; so we must consider them separately, and the two sets of machinery which slowly developed from their application.

MAGNETO-ELECTRIC AND DYNAMO-ELECTRIC MACHINES.

In 1820 the great Faraday succeeded in rotating a system of wires through which ran currents, by means of a permanent magnet placed near it, but he did not grasp the practical importance of his discovery, and it was reserved for Pixii, a French manufacturer of physical instruments, to make, in the year 1832, the first magneto-electric machine, *i. e.*, a machine for inducing currents of electricity in a wire or coil of wire by means of a magnet. Pixii revolved the poles of a horse-shoe magnet before the poles of a double electro-magnet. Thus two conductors changed their relative positions, and since one was traversed by a current, in accordance with Lenz's law a current was induced in the other. As this machine had the mechanical disadvantage of having the heavier part (the permanent magnet) put in motion, a change was soon made, so that instead, the magnets were fixed and the coils rotated. For many years after this step no material advance was made in their construction. They were unsatisfactory in use, because their effect did not increase proportionally to their dimensions, and therefore machines for the production of powerful currents were cumbersome and costly.

Werner Siemens and Mr. Wheatstone almost simultaneously, and quite independently, discovered the principle which puts our electrical generators so far ahead of those of half a century ago, viz., the principle of the accumulation of currents by their mutual action on one another. In a machine constructed on this principle the permanent magnet is replaced by an electro-magnet, which is put in the same circuit with the coils of the other electro-magnet revolving before it. There is always enough magnetism in the coils of the other when the machine is started. This induced current in the second induces a still stronger current in the coils of number one, and this new one added to the little one already there induces yet a stronger one in number two, and so it goes, back and forth, the strength of the current produced being limited only by the capacity for saturation which the coils possess. In this way a trace of magnetism suffices to originate torrents of electricity. Such a generator is commonly called a dynamo-electric machine.

Just here a few words about the terminology of the subject in hand. A machine using the principle of Pixii's, described above, *i. e.*, having permanent magnets and revolving coils, is called a magneto-electric machine, because "by a magnet electricity" is produced. On the other hand, where the principle of mutual accumulation by electro-magnets is employed, the term dynamo-electric—"by power electricity"—is applied. In point of fact, dynamo-electric and dynamo-magneto-electric would respectively be more accurate terms, but the others are in more common use. Later we shall come to a class of machines in which an electrical current generated by chemical means is transformed into power, and these are known as "electro-magnetic," without any real reason for the name, except that electricity and magnets are essential to their working. No distinctive name has been applied where a current generated by power is employed, but since we call the generator a "dynamo-electric" machine, we may for the same reason call the motor an "electro-dynamic" machine, for here we have "by electricity, power." For the sake of brevity, "dynamo-electric" is often shortened into "dynamo." I shall take the same liberty with "electro-dynamic" in calling the two sets of machines respectively "dynamos" and "electros." The armature is the soft iron core with coils of insulated copper wire about it which revolves between or before the poles of the magnets or magnet.

A commutator is a device for taking the currents off the armature of a dynamo and uniting them into one which shall flow continuously in one direction. There are many different arrangements in use for this purpose, but the explana-

tion of one will be sufficient to show the principle of all.

Suppose D to be the shaft of an armature made of two pieces of copper, A and C, with a strip, B, of ivory or some other non-conducting substance between. A is connected with one end of the coils in the armature and C with the other.

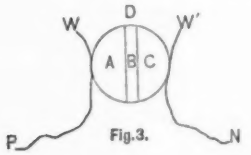


Fig.3.

As the armature revolves between the poles of an electro-magnet, half its coils are always leaving the south pole of the magnet and going toward the north pole, and as the north pole induces the same sort of a current in the wire coming toward it as the south pole does in the wire going from it, the currents in that half of the armature will have the same direction, and *vice versa* the currents in the other half will have the opposite direction. When these halves pass the pole, the direction of the currents in them is respectively reversed. But at the same time the connection between the strips A and C and the wires W and W′ is reversed, so that a positive current, P, will always flow from one wire, and a negative, N, from the other. The wires W and W′ are kept pressed against the revolving shaft by springs. The sparks seen when the dynamo is in motion are caused by the imperfect connections made by these wires, or commutator brushes, as they are called. They are the only parts of a dynamo liable to wear and tear, and as they can be easily replaced, the item of repairs is, or ought to be, very small in the cost of running the machine. The only difference between various machines lies in the arrangement of coils, cores, armatures and electro-magnets. Effects of tension (intensity) or quantity are produced by using fine or coarse wire in the coils.

Under the head of the transmission of electricity it will be enough for the present to state what may seem a truism, viz., that a considerable current of electricity can be transmitted over a wire to a long distance. Let us now consider the history and principles of those machines that convert the electricity into power.

Among the many experiments which Faraday made in electrical science, after the discoveries of Ampere and his contemporaries, were some to ascertain the effects of currents upon one another and upon passive conductors. As we have seen, Ampere discovered the attractive and repulsive powers of currents, and no doubt was the first actually to produce motion by means of electricity, but Faraday was the first to make any extended experiments in this direction, and he should have the credit of first bringing the motory powers of electricity into prominence. It has been claimed that the first machine actually moved by "electro-magnetism," as it used to be called, was invented by Professor Henry, of Albany, New York, consisting of an oscillating beam surrounded by a conductor of insulated wire and two stationary magnets. The proofs advanced in support of this claim are not positive. However that may be, it seems to be well established that the first rotary motion by means of an electric current was the production of an American, one Thomas Davenport, of Brandon, Vermont. His claim to this honor has not of late years been pushed or even published, and the man and his invention have been forgotten. Still there is positive evidence that in 1834 he invented and exhibited an electro-magnetic engine. If any European produced a rotary motion in this way before this date, I have been unable to ascertain it. I beg leave here to put in a plea for Mr. Davenport, and to claim for America the honor of first utilizing the force which is destined to revolutionize the mechanical systems of the world. The originality of this plea may be judged when we read among the writings of the celebrated physicist, Ganot, that "M. Jacobi, of St. Petersburg, was the first to construct an electro-magnetic machine, with which, in 1838, he moved on the Neva a small boat containing twelve persons." By reference to the Boston papers of the year 1835, it will be seen that in that year Davenport exhibited in Boston an electro-magnetic engine running on a small circular railway. Three years before Jacobi's boat swam the waters of the Neva, Daven-

port's engine, the result of American application, of American perseverance, of American intelligence, ran along the rails, giving America the honor of being the first to harness the giant force and compel it to do her bidding. To the combined minds of England, Italy and Denmark, we owe the discovery of "electricity by power," but to America, to Professor Henry and Thomas Davenport, we owe the discovery of "power by electricity."

After Davenport's discoveries, Prof. Page, of Washington, took up the subject and made many practical inventions. Among them was a large and efficient electro-magnetic engine of sufficient power to propel a railway car with considerable velocity. It would be interesting to touch upon some of the others, but they are hardly relevant. I would only mention a fact little known at the present day, viz., that Prof. Page has shown very strong evidence to prove that the honor of inventing the Ruhmkorff coil should be given to him. Here again America was possibly several years ahead of Europe. My authority for this, and for the statements about Davenport's invention, is Silliman's *Journal of Science and Arts*. A pamphlet on "The History of Davenport's Invention of the Application of Electro-Magnetism to Machinery" gives much information on the subject.

ELECTRO-MOTORS.

The most elementary arrangement for producing motion by electricity would be, of course, a simple mechanism operated in accordance with Ampere's laws, that two parallel currents in the same direction attract, and in opposite directions repel, one another. If we place a magnet so that it may move freely before the poles of an electro-magnet, and if by clockwork, or some other device, we send a current in alternate directions through the coils of the electro-magnet, then, since in accordance with the Amperian theory a current is continually flowing around the permanent magnet, the latter will be alternately attracted and repelled. In other words, the current of the electro-magnet will have produced motion.

The simplest electro-motor is Froment's rotating engine. This consists of an electro-magnet radially outside the periphery of a drum capable of rotation. On this periphery are a series of soft iron coils. As the drum revolves it completes a circuit, by suitable make and break pieces sending a powerful current from a battery through the electro-magnet as each coil approaches the pole within 15° or 20°; the electro-magnet then attracts the armature, and the drum is forced to continue its revolution. The circuit is interrupted as the coil passes the electro-magnet and the magnet therefore unmade. The drum continues its rotation by inertia, or by the action of another electro-magnet, until a second coil approaches the poles of the first electro-magnet, when the circuit is made as before.

Jenkin in his "Electricity and Magnetism," says: "Another form of electro-motor is constructed resembling the ordinary beam steam engine; the piston is represented by a magnet which is alternately sucked into a hollow coil, and repelled as the current in the coil is reversed; sometimes a soft iron piston is used, which is alternately attracted and set free.

"Much more attention would be directed to electro-motors than they have hitherto received, were it not for the fact that they are necessarily at least fifty times more expensive to maintain in action than the ordinary steam engine. Zinc is the cheapest metal by the consumption of which electricity is produced. The energy evolved by the consumption of one grain of zinc is only about $\frac{1}{10}$ of that developed by the consumption of a grain of coal. A large fraction of the energy in the case of the zinc can be converted into an electric current, whereas we have not yet discovered any means of obtaining the energy of coal except as heat, and we necessarily waste a great part of this heat in the process of transforming it into mechanical energy. In the transformation of energy into mechanical effect the advantage lies with electricity. The whole of the energy either of heat or of an electric current can never be transmuted into mechanical effect. In the best steam engines not one quarter of the heat is so transformed; more frequently about a tenth is used. It is probable that larger fractions of the total

energy than these could be transformed by an electro-motor into mechanical effect; but this advantage, even if realized, cannot nearly counterbalance the disadvantage entailed by the cost of zinc, which is 20-fold that of coal, weight for weight, 200-fold that of coal for equal quantities of potential energy. In estimating as above, that the zinc motor may be only 50 times as dear as the coal motor, I assume that the electro-motor may be four times as efficient as the heat engine in transforming potential into actual energy."

Electro-motors have assumed a new importance since the invention of dynamo-electric machines has made pos sible the production of electricity at such a comparatively small expense. The only trouble with Davenport's invention, with Page's engine, and with the innumerable other motors which have promised literally to electrify the world, has been the comparatively high cost of obtaining electricity to run them. Now that the dynamos can be run so economically, the question of electro-motors assumes a more important aspect. It is this that gives to the subject of the transmission of power by electricity interest and importance.

ELECTRICAL TRANSMISSION THEORETICALLY CONSIDERED.

For many years the two sciences of magneto-electricity and electro-magnetism were growing up, developing, side by side. But at last some one saw what they had in common, united them, and, lo! a new science sprang into being. The exact time of the origin of the idea of using the electricity generated by power to produce power in turn, and the identity of the man who conceived it are alike uncertain. J. Chrétien states that the first attempt to transmit motive power by electricity was made in 1873, at the Vienna Exposition, by H. Fontaine. Certainly in 1876 at Philadelphia, and in 1878 at Paris, the experiment was made. It is enough for us that, to-day, the electrical transmission of power is an accomplished fact.

The underlying principle in this transmission is the coupling of two or more dynamos. Let the current generated by one flow over a short circuit, and let another machine be placed in the circuit; then the electro-magnet of the second will become excited and a current will also pass through the coils of the armature. By Ampere's law two currents attract or repel one another according as they run parallel or in opposite directions. Suppose in this case the first motion is repulsion and the armature begins to rotate. As its coils respectively approach the pole opposite the one by which they were repelled, they will be attracted. As soon as they pass the pole, the commutator will have changed the direction of the current and they will be repelled. On approaching the original pole from which they started, they will be attracted, since the current still remains inverse. We have now followed the armature through an entire rotation. This rotation will evidently be kept up, and the stronger the current the faster the armature will turn. By connecting shafting with this revolving armature the power may be utilized.

It has now been shown, first, that power can be made to generate an electric current; second, that an electric current can flow to a considerable distance; third, that an electric current can generate considerable power; in other words, that electric transmission is possible. The question now comes up, is it practicable? To answer this we must first ascertain two things: (1) How much power can be advantageously employed? and (2) How much of it can be reclaimed?

As to (1), we know by repeated experiment that up to a certain point, not far from 50 revolutions of the armature per second, the strength of the current produced is essentially proportional to the speed of rotation. If a strength of current is desired greater than given machines will produce with a rotation of 50 turns to the second, the size or number of machines employed may be increased, so we may conclude for practical purposes that an indefinite amount power may be employed.

As to how much power can be reclaimed, there has also been much experiment, and the scientists do not altogether agree; but as nearly as I can judge from the various results obtained, I am warranted in setting the practical efficiency of a dynamo at about 85 per cent. That is to say, about 15 per cent. of the

power expended on a dynamo will be lost in the process of conversion into electricity.

It might be inferred that if an exactly similar dynamo were used as an electro (a motor), its efficiency would be 85 per cent., and, therefore, leaving out of account the transmission of the electricity, 85 per cent. of 85 per cent. might be reclaimed. But here another factor comes in, viz., the induction of counter-currents in the electro, which is the practical hindrance to reclaiming so much as this. As has been shown, when a current is conducted into the coils of the electro, the armature will begin to revolve. Its rotation is exactly the same as it would be if the motive power came from a pulley belt attached to its wheel. The result is that currents are induced in the coils. But these currents are directly the opposite of those which are produced by the dynamo and which are giving the armature of the electro motion. These counter currents lessen the effect of the direct current from the dynamo proportionally, and the faster the revolution the stronger the counter-currents. Then, since the strength of the current from the dynamo is greatest when the electro is at rest, it will be readily seen that when the most work is obtained from the electro, its armature is revolving at one-half the speed of that of the armature of the dynamo. Hence, if two equal machines are arranged for the transmission of power, the amount of work reclaimable from the second machine will be in general 50 per cent. of that employed on the first. This, of course, leaves out of account friction and the efficiency of the two machines. If we allow 10 per cent. loss for the former, and 25 for the latter, we have left but 65; and as 50 per cent. of this is lost by the production of counter-currents, we finally secure from the electro but between 30 and 35 per cent. of the power originally employed. Even if the loss be as great as this, the transmission would be not only possible but very profitable.

The question of the amount of power reclaimable was the subject of much discussion in connection with experiments made at the Electrical Exhibition in Munich, in the fall of 1882, by M. Marcel Deprez. He succeeded in transmitting power from the village of Weisbach, a distance of 57 kilometers, over an ordinary telegraph wire. The insulation was good, but differed in nothing from that usually employed on all telegraph lines. A heavy rain fell during almost the whole duration of the experiments. In the first of these there was immediately obtained at Munich a speed of 1,500 revolutions per second, the generating machine moving at the rate of 2,200. "The two machines being identical," said Deprez, "the proportion of the work recovered at Munich to the work expended at Munich was, setting aside passive resistance of every kind, $= \frac{1,500}{2,200}$, or more than 60 per cent." These figures were subsequently sharply criticized in the *Electrical Review*, by the electricians Hospitalier and Cabanellas, and Deprez was finally forced to admit that while the electrical result, as he termed it, varied from 50 to beyond 60 per cent., the industrial result varied only from 25 to more than 35, according as the generator turned at 1,600 or 2,000 revolutions. As perfect insulation was supposed, and other inacceptable hypotheses were assumed, the official report of 38.9 per cent. reclaimed can only be accepted under the most express reserve. The real amount of industrial work reclaimed was probably about 20 per cent. Taking into consideration the unfavorable circumstances, the fact that ordinary telegraph wire with ordinary insulation was used, and that the dynamos were not suitable for the experiment, it will be seen that the results do not disprove the conclusion that for practical purposes between 30 and 35 per cent. can be reclaimed, but rather go to substantiate it.

OBJECTIONS ON THE SCORE OF HEAT.

As Mr. Siemens has said, the principal objection that has been raised by electricians to the conveyance of power to the distance of miles is on account of the apparently rapid increase in the size of the conductor required with increase of distance. Many writers have given their views on this point, some maintaining, others opposing, the idea that a serious difficulty on this score is to be anticipated. In an able paper presented to the Franklin Institute some time ago by

Professors Thomson and Houston, it was conclusively shown that the thickness of the conductor required is of no particular moment. Their statements had particular reference to the size of cable necessary to convey the power of Niagara to New York City. One electrician had asserted that such a cable would require more copper than exists in the enormous deposits about Lake Superior. Another estimated the cost of the cable at $60 per lineal foot. But the Professors mentioned clearly proved that without increasing the size of the wire the same current can be sent to any distance, provided the number of dynamos be increased or diminished in proportion. "Stripped of its theoretical considerations," they concluded, "the important fact still remains, that with a cable of limited size an enormous quantity of power may be transmitted to considerable distances."

Sir William Thomson ascribes the credit of originating the idea of utilizing Niagara to Mr. C. W. Siemens, in March, 1877. In May, 1879, Thomson stated before a committee of the House of Commons that, taking Niagara as an example, under practically realizable conditions of intensity, a copper wire of half an inch in diameter would suffice to take 26,250 horse-power from water wheels driven by the falls, and (losing only 20 per cent. on the way) to yield 21,000 horse-power at a distance of 300 British statute miles; the prime cost of the copper amounting to £60,000, or less than £3 per horse-power, actually yielded at the distant station. In his inaugural address to the British Association in 1881, he gave a solution to the problem of what was to be done with the enormous electro-motive force at the New York end of the wires, which consisted in the use of large numbers of accumulators. All that is necessary to do, in order to subdivide this enormous force of 80,000 volts into what may be called small commercial electro-motive forces, is to keep a Faure battery of 40,000 cells always charged direct from the main current, and apply a methodical system of removing sets of 50 and placing them on town supply circuits, while other sets of 50 are being regularly introduced into the main circuit that is being charged. Of course, this removal does not mean bodily removal of the cells, but merely disconnecting the wires.

On looking over the views of different electricians, I can but come to the conclusion that the question of the size of conductors necessary for the transmission of power depends solely on the question of how much heat will be developed, and how it can be got rid of. Our doctrine of the conservation of energy teaches us that the heat developed is but another form of the wasted power. Now it seems to be agreed that when we allow the electricity to work a machine, as well as flow through the circuit, the power wasted is proportional to the square of the current or the velocity of the flow. Then, of course, the bigger the current the more the power wasted, and the more heat developed. But as Professors Thomson and Houston clearly demonstrated, the electromotive force can be indefinitely increased without altering the current, provided the resistance be likewise increased. The latter can be done without increasing the section of the conductor, by increasing its length. Therefore, by allowing only a very small current to pass through the wire, and by maintaining a very great electro-motive force, the amount of power transmitted can be made as large as we like, and the waste from the passage of the current as small as we like.

Then we conclude that however long and thin the wires may be, electricity may be brought from any distance, however great, to give out almost all its original energy to a machine, and that this requires a great difference of potentials; in other words, great electro-motive force, and a small current; and that, finally, the objections on the score of the size of the conductor, the heat generated, and the power wasted, three mutually dependent subjects, are invalid. In other words. it may be considered as indubitably proved that theoretically the transmission of power is feasible. It remains to be shown what has been practically accomplished in this direction.

PRACTICAL APPLICATIONS.

The most important use to which the principle of electric transmission of power is at present being put, is the running

of railway cars. It was only a little over five years ago that the first electric railway was built—an experimental one—in Germany, and to-day there are many in that country where their practical success has been first demonstrated. In France and England they are fast becoming popular, and it seems strange that those in America are yet all of an experimental nature. In this branch of electrical science at least, America is far from foremost.

The advantages of electricity over steam for railway purposes are many and great. In the first place the bulky locomotive is done away with, as the electro, or motor, can be placed either under the car or on trucks by itself, in either case great weight and room being saved. The machinery for converting the coal into the power, or rather extracting the power from the coal, is not portable, but stationary, and can be placed in the most convenient spot, even water-power thus being made available. For transmitting the power in many cases no difficulty has been experienced in using one rail as the positive and the other as the negative conductor. Sometimes it has been found that the dirt sticking to the rails and the felloes of the wheels formed a sort of crust so insulating as to prevent adequate communication. To remedy this, tubes have then been hung on poles beside the track with longitudinal slots on their under sides. In these run wheels connected with the electros, or motors, on the train. The tubes act as conductors, and the movements of the wheels in the tubes correspond to those of the cars, so that a good and constant communication is secured.

Far steeper grades can be surmounted on an electric than on a steam railway. Several carriages, each equipped with a motor, can be joined to one tram, which will give a distribution of motive power sufficient to overcome great inclines, or electro-magnets can be attached to the car directly over the rails, so that when they are thrown into connection with the current the car is pulled, as it were, toward the rails, and the adhesive power of the wheels is increased wonderfully. In this way the adhesive power of a 10-ton electric locomotive becomes greater than that of a 40-ton steam locomotive. Inclines of 2,000 feet to the mile have been surmounted with the electric locomotive.

As to speed, it is impossible to give the limit which can be reached on electric railways, because those so far constructed are on streets or in localities where very rapid transit is not possible or desirable. On the very first one built a rate of seven miles per hour was customary. On the Berlin railway, opened in 1881, the greatest speed reached was at the rate of 18 miles per hour. More was possible, but the police authorities refused to permit more than 9 miles per hour. Up to August, 1882, there had been no breakdown on this road, but Dr. Siemens acknowledged that in the winter the loss of power was more than quarter of the power supplied, a fact which indicates one of the barriers to complete success in electrical railroading. On the Siemens' railway, at the Paris Exhibition of September, 1881, a distance of over 1,600 feet was traversed in a minute, which is at the rate of nearly twenty miles per hour. There is every probability that electric locomotives can be run faster than any steam locomotive now in use.

By a happy coincidence, which belongs to the very nature of the electric motor, the static effect is maximum when the motor is in repose. This renders the starting very easy.

Economy is a most vital question. The electric locomotive can be built a great deal more cheaply than the steam locomotive. No coal has to be carried, and the coal used can be of a cheaper quality. Huge repair shops are wholly unnecessary. One man can run the electric locomotive; electric brakes are by far the strongest and most trustworthy. It is claimed that an electric car can be run on street railroads at one-fourth the cost of a horse car. This problem is wonderfully simplified by the utilization of some kind of secondary batteries, or accumulators, as they are called. By their help the electricity can be manufactured at any time and place convenient, and stored until it is required to be used. This, it is evident, will do away with the intricate and cumbrous paraphernalia of posts, wires, transversers, etc. Prof. W. E. Ayrtoun said, in March, 1882, that using only a single cell of Faure's accumulator, about 300 lbs. dead weight

contains all the energy and all the machinery necessary for over ten miles' run of a tram car with 46 passengers. In spite of the temporary character of the arrangement at the time in use at Leytonstone, the total weight of the Faure cells, dynamos and gearing combined, was only one and a-half ton, or one-third the weight of the detached steam or compressed air engine commonly used for tram cars. In a ton of the cells, as at present constructed, there is about 50 miles' run of a tram car containing 46 passengers. Electric storage of energy, moreover, makes us nearly independent of accidents to the engine or dynamo machines, or irregularities in their working, while the process results in no considerable loss of power.

Since March, 1882, an electrical railway has been in operation at Breuil-en-Auge, France, with great practical success. The Faure accumulators in the tender supply the electricity to the dynamo used as a motor. This railway is the property of a large bleaching establishment, and runs through the bleaching fields to pick up the linen. When the train stops, the dynamo is thrown into gear with a set of windlass rollers employed to wind up the linen. With it a single workman can do in 30 minutes what it used to take 11 hours to accomplish. A steam engine would never do in a bleaching field, and the application of electricity in such a case is not only novel, but suggestive. The public may soon insist that its lungs and ears have as much claim as the linen of the bleaching field, to be protected from the smoke and cinders of a steam engine.

One of the principal advantages of electrical railways, not suggested above, is that by properly arranging the connections, a train running into a section already occupied by another train will be brought to an immediate standstill and will remain at rest until the preceding train has passed out of that section. This will reduce the dangers of railway traveling, as far as collisions are concerned, to a minimum.

Although the application of electricity to the running of railway cars is almost the only direction in which the art of transmitting power by the electric current has made any practical advancement, in many other lines experiments have been made which show the vast possibilities of this art. A few instances may be interesting. Professors Thomson and Houston succeeded in transmitting considerable power through a wire only 0.004 inch in diameter. Important experiments upon ploughing by electricity were made in France early in 1879, which showed that for this purpose electricity can replace steam with advantage and economy. Since that time great progress has been made in pumping, pile-driving, punching, sawing, sewing, embroidering, weaving, printing, etc., by electricity. In short, enough has been done to show that methods, not possibilities, are now the things to be considered.

CONCLUSIONS AND SPECULATIONS.

What I have said will suffice to show that out of the science of dynamical electricity is fast developing an art. For a century scientists have been studying this most subtle force, and have been paving the way for the work—the useful, practical work which is to follow. The world has every reason to believe that artists will now step in and apply the principles that the scientists have discovered and the laws that they have formulated.

The possible applications of the principle of the electrical transmission of power are almost numberless. All the uses to which the energies of steam, water or compressed air are now turned, may be subserved as well by electricity, and this may be generated in places far more convenient than those now usually employed for the conversion into active energy of any of the forces latent in nature. We shall, I believe, at no distant date, have great central stations, possibly situated at the bottom of coal pits, where enormous steam engines will drive many electric machines. We shall have wires laid along every street, the electricity tapped into every house, and the quantity of electricity used in each house registered as gas is at present. The storage battery will fill a place corresponding to the gasometer in the gas system, making the current steady, rendering the consumer independent of the irregular action or stoppages of the dynamos of the central station, and enabling the use of dynamos of the highest tension, *i. e.*, those which produce the

currents of the greatest intensity. The electricity will be passed through little electric machines to drive machinery, to produce ventilation, to replace stoves, and to work all sorts of apparatus, as well as to give everybody an electric light. Solar heat will be used to run the dynamos in the cloudless regions. Everywhere the powers of the tides and such waterfalls as Niagara are to be utilized. Is not a millennium to be anticipated when the water power of a country shall be available at every door?

Electrical transmission has the unparalleled advantage of being superior to the obstacle presented by distance. Then again, it operates its miracles in perfect silence and repose. No force appears in the conductor such as appears in shafting, in pipes with compressed air or water, in endless chains or belts; and, in case of powerful currents, insulation is easy. The conductor is inert, and can be bent or shifted in any way whilst transmitting many horse-power, provided, of course, its continuity be not interrupted. It can be carried round the sharpest corners, through the most private rooms, into places where no other transmitter of power could possibly be taken. There is nothing to burst or to give way. In short such a method of transmission would be the acme of dynamical science.

In other ways electricity has long been serving mankind. The Ruhmkorff coil, the telegraph, the telephone, are but the most important of the mechanisms so far devised for its application. Now, it is proposed to utilize more fully nature's other forces by means of this strange and novel agency—to carry the power of the coal bed, the waterfall, the ocean, to localities where it can do work. The power which is daily wasted in a hundred ways—enormous, immeasurable as it is, will some day do its share toward the support and the advancement of the human race. Steam, which in the last century has conferred so many benefits on the world, will give way before electricity. The dynamo will replace the steam engine. This prediction seems wild and visionary, yet when steam was first thought of as an available force, its advocates were considered, just as the advocates of dynamical electricity to-day are considered—mere enthusiasts. But public opinion never stops the march of intellect. After it had proved the powers of steam to be enormous, genius never halted, but straightway went on anticipating still more wonderful discoveries in the realms of electricity.

The prophetic ken of science was happily exhibited by Dr. Lardner in his treatise on the Steam Engine. "Philosophy," said he, half a century ago, "already directs her fingers at sources of inexhaustible power in the phenomena of electricity and magnetism, and many causes combine to justify the expectation that we are on the eve of mechanical discoveries still greater than any which have yet appeared; and that the steam-engine itself, with the gigantic powers conferred upon it by the immortal Watt, will dwindle into insignificance in comparison with the hidden powers of nature still to be revealed, and that the day will come when that machine which is now extending the blessings of civilization to the most remote skirts of the globe will cease to have existence, except in the page of history."

To-day we are beginning to appreciate the truth of this prophecy. To-day we see dynamical electricity in the forefront of the physical sciences. The principle of the transmission of power by electricity fast approaches its realization. We are, in truth, just entering upon a wonderful age.

FAULTY CONSTRUCTION OF THE Y LEVEL.—When adjusting for parallelism of attached level to line of collimation great annoyance is caused by want of balance of the telescope with its attachments. In most instruments the eye end is very much lighter than the object end, and if the tripod be old and springy, and especially if the bubble be sensitive, it is impossible to get a good adjustment without temporarily weighting the eye end. A properly contracted telescope, when taken out of the Y's, should balance when supported by a cord passed between the bubble tube and the telescope at the point where the vertical axis cuts the barrel. This balance can easily be secured in every instrument by setting the collars at the proper relative distance from the ends of the telescope. It is not necessary that the eye piece and object glass should project equally beyond the Y's, and yet makers seem to think it essential. If they would sacrifice symmetry somewhat they would add greatly to the utility of their instruments.

If engineers will give this point due consideration, makers will be led to correct their present faulty construction.—R. G. KIMBALL, Polytechnic Institute, Brooklyn.

ACCOUNT OF THE SWISS PRECISION-LEVELING.

By R. GUISAN.

Translated from "Compte-rendu de la Société des Ingénieurs-civils," for Abstracts of Inst. of Civil Engineers.

As the Swiss were obliged to base all their levelings on bench-marks whose values were fixed by their neighbors, very contradictory results were introduced into their work. An international geodetical commission was accordingly held at Berlin in 1864 to frame rules for precision-levelings which should be common to all central Europe. At this it was resolved that side by side with the trigonometrical determination of heights, these levelings should be executed by the method of equal sights, the necessary checks being obtained by the polygonal combination of stations. The Swiss portion was commenced in July, 1865, under the directions of Messrs. Hirsch and Plantamour (the directors respectively of the Neufchatel and Geneva Observatories), and it will be finished this year (1884).

The instruments used were Ertel's levels on a modified form, having telescopes magnifying forty-two times, fitted with three horizontal stadia cross-hairs, the angle subtended by two threads, being about 3′ 30″. Each of the twenty divisions of the bubble scale was tested by the meridian-circle at Neufchatel, and corresponds to about three seconds of arc. The staves, which are three meters long, are made of very dry pine and graduated to centimeters, black and white alternately, the even numbers being written on one side, the odd on the other; these staves are provided with a box-level and plummet, and their feet are tipped with an iron cylindrical spur which fits in a hole pierced in an iron tripod. The staff holder grounds his staff firmly by a blow of its butt, after which it can be rotated without fear of displacement between the back and fore sight. On bad ground or in wind the staff is braced to keep it truly vertical.

Before commencing field work, as also at its close, the three instrumental constants are very carefully determined; they are:

1st. The angular value of the bubble scale-graduations.

2d. The angular reduction of the mean of the three threads.

3d. The angular distance of the two outer threads.

The method of doing this is detailed at length by the author, and he further shows clearly that by the system of leveling adopted curvature and refraction may be safely neglected.

The staff length is a most important factor in leveling, and this was most carefully and frequently tested. To find the equation for the two staves per meter, two benchmarks in bronze were let into the rocks in front of the Neufchatel Observatory at a difference in height of 2.90 meters. The instrument was set up exactly midway between them (at thirty meters), and their difference in level was read on each staff successively at varying heights of the instrument. The absolute staff length was tested by the standard at Berne, and this latter will be compared this winter (1883-1884) with that at Paris, when, on the completion of the leveling, final values will be given to all the readings taken. From the comparisons already made, the staff length is not affected by moisture, and only very slightly by temperature; its changes are not proportional to the interval elapsing between the comparisons, nor are they systematic, as they vary accidentally as much in one direction as in another.

The principle of completely separating the observations from the calculations was adopted. The original field books are copied, the originals being sent to Neufchatel, and the copies to Geneva, where the reductions are made in duplicate. To simplify the work and reduce the expense, the polygon system is adopted, and where this is impossible the line is leveled twice over. The work is repeated, in either case, if it does not close satisfactorily. Amongst the chief rules of procedure are the following:

1. The leveling to be executed by equal sights whenever possible; the difference between length of back and fore sights never to exceed ten meters.

2. The length of sight is as a rule to be limited as under:

(*a.*) Upon railroads with gradients under 1 in 100 to 100 meters.

(*b.*) Upon railroads with steeper gradients from 50 meters to 100 meters.

(*c.*) Upon highroads in the plains from 30 meters to 60 meters.

(*d.*) Upon mountain roads, from 10 meters to 25 meters.

3. The spirit-level to be always shaded from the sun.

4. The three instrumental errors, viz., collimation of optical axis, inequality of pivots, and bubble-error, to be determined at least once a day.

5. The field work to be carried on continuously except on wet or windy days; 3 kilometers at least should be the length of line leveled per day along railways, and 2 along roads in the plains.

6. Bench-marks to be made at every kilometer, and to be clearly described in the field book.

For adjustment of the errors made in the field Messrs. Hirsch and Plantamour have applied the method of least squares on the following principle: Two approximations are obtained, and both are based on the supposition that the closing error of a polygon equals the arithmetical and not the algebraical sum of the errors made in its different sides. This supposition, though not exact, is necessary for the solution of the conditional equation. Two values for the correction to be applied to a side are found from each polygon of which it forms a part; one by taking into account accidental errors only; the second by taking into account errors due to change of length in the staves. The probable mean of the correction for each side is then obtained, and, by comparing each individual value with this mean, allowing for the weights assigned, the mean error of each correction just found. The closing error having been thus reduced, the second approximation is applied, in which the mean error of the correction found by the first approximation is taken as the measure of the accuracy of the different sides. Fresh corrections, as well as the mean errors of such corrections, are again obtained, and with these new values the closing errors of the various polygons are reduced to a minimum. An example is given in illustration, as also a table, by which it appears that in six sides, together measuring 272 kilometers, the mean error per kilometer is below 1 millimeter.

In verifying work either by duplicated leveling or by closed polygons, a discrepancy of 0.0007 meter per kilometer in the two results is allowed on favorable ground, and of 0.0050 meter on unfavorable. In the Swiss work, the mean error per kilometer has consequently been—

1. In duplicated leveling—
   (*a.*) On ten favorable lines measuring 416 kilometers 0.0014 meter.
   (*b.*) On twenty unfavorable lines, measuring 830 kilometers, 0.0085 meter.
2. In nineteen closed polygons, whose sides measure 6,693 kilometers, 0.0030 meter.

Leveling lines the second time in the opposite direction has sensibly improved the closing of polygons.

During the progress of this work twenty benchmarks have been placed on the boundaries of countries conterminous with Switzerland, and it now only remains for an international congress to agree upon a common datum level, which should *a priori* be a point along the Mediterranean, to allow a comparison between the precision-levelings of all central Europe.

[*Note.*—In a note the author remarks that the settlement of the instrument makes the fore sight less than it should be, and proves from the leveling of thirteen lines with steep gradients that the difference in level is invariably greater in ascents than in descents. Mr. Hirsch, however, replies that in a work he is now engaged on this question is fully discussed, but that the effect of settlement —all other things being equal—depends rather on the length of the line leveled than on its difference in level.—TRANSL'R.]

M. Daubrée presented to the French Academy at its session of December 1st., the treatises of Mr. Cope Whitehouse on the caves of Staffa. The highest French authority on this subject has thus expressed approval of the cogency of the arguments by which the American *savant* has shown that the popular opinion of the formation of Fingal's Cave by the sea is untenable, and that it must be referred to the agency of man, and probably of that race which has left its traces in other great works in stone on the Irish and Scotch coasts.

OBITUARY.

JOHN B. JERVIS.—The venerable John B. Jervis, the Nestor of American engineers, has at last passed away, at the great age of 89, which he reached with fewer of the infirmities than usually attend so great an age. Mr. Jervis was already a prominent engineer when the first American railroad was built, and it was by his recommendation as Chief Engineer of the Delaware & Hudson Canal Company that his young assistant, the now venerable Horatio Allen, was sent to England before the construction and trial of the "Rocket," to order locomotives for the railroad which this company was building through the woods of the Northeastern Pennsylvania, to carry coal from the mines to its canal, the story of which was recently told in these columns by Mr. Allen. As one of the few men of reputation in the engineering profession in this country at the time we began to build railroads, Mr. Jervis had an important part to play, and he remained a leading railroad man until, already many years ago, advancing age led him to retire from such active duties.

Mr. Jervis began at the very bottom of his profession, in 1825, as axeman on the Erie Canal during its construction. Later he became Chief Engineer of the Delaware & Hudson Canal, and its canal and railroad were built under his direction.

In 1831 he was Chief Engineer of the Mohawk & Hudson Railroad, the line from Albany to Schenectady which now forms part of the New York Central & Hudson River Railroad, and the next year he designed for it a locomotive with a swiveling truck, which has since become almost universal on American railroads, and the use of which is now rapidly spreading in Europe. In 1836 he became Chief Engineer of the Croton Aqueduct, which is generally regarded as his great monument, and one of the finest engineering structures in the country. There were no precedents in this country for a structure of this kind, but the results attained were precisely what Mr. Jervis had estimated, and the cost differed from his estimates by only 1 per cent.

In 1849 Mr. Jervis became Chief Engineer of the Hudson River Railroad, and not only took charge of its construction, but argued in favor of its financial success, at a time when few thought it possible for a railroad to secure a paying traffic alongside a stream so favorable to navigation as the Hudson.

The Hudson River Railroad having been completed in 1851, Mr. Jervis became connected with Michigan Southern & Northern Indiana, the Chicago & Rock Island (of which he was President in 1854), and the Pittsburgh, Fort Wayne & Chicago, but it is already many years since he retired from active railroad management. Having built the first railroad in America on which a locomotive ran, he lived to see the country covered with a net-work of 125,000 miles, which in methods of construction and in the character of the rolling stock used bears the impress of his ideas and those of the other pioneers in railroad building.—*Railroad Gazette.*

REPORTS OF ENGINEERING SOCIETIES.

AMERICAN SOCIETY CIVIL ENGINEERS.—At the meeting held Wednesday evening, January 7, Col. Wm. H. Paine presiding, the following persons were declared as elected to membership:

Members—Peter Lather Archibald, Chief Engineer, Maintenance of Way, Intercolonial Ry., Moncton, New Brunswick, Canada; Chas. Sumner Henning, Resident Engineer in charge of Maintenance of Way, Atlantic and Pacific R. R., Peach Springs, Arizona; Chas. Maples Jarvis, Vice-President and Chief Engineer, Berlin Iron Bridge Co., East Berlin, Conn.; Henry Ward Beecher Phinney, Resident Engineer, Harlem River Bridge, Suburban Rapid Transit Co., New York City.

Juniors—William Ferris Booth, C. E., Poughkeepsie, N. Y.; Edward Fladd, Ass't Engineer St. Louis Waterworks, St. Louis, Mo.; Sinclair Joseph Johnson, Ass't Engineer Harlem River Bridge, Suburban Rapid Transit Co., New York City.

The following amendment to Section 19 of the by-laws of the Society was adopted by a general vote:

Section 19.—A nomination or proposal shall be presented at the next regular meeting of the Board of Direction following its receipt; *the Board of Direction shall thereupon send to all members of the Society a notice that such person is a candidate for election. Not less than thirty days thereafter the Board shall consider the application, and, if approved,* and the applicant (if for admission as member, associate or junior) classed with his consent, a day shall be fixed for the ballot to be canvassed, which shall be at a regular meeting of the Society, not less than twenty-five days thereafter.

The amended portion is in italics.

The paper of the evening was by Prof. Robert H. Thurston, on "The Real Value of Lubricants, and the Correct Method of Comparing Prices"; this paper was read by the Secretary, and discussed.

Mr. M. Eisller, C. E., followed with an interesting description of the geology of the Isthmus of Panama, as found along the line of the canal. Mr. Eisller referred especially to the disintegrated character of the trachite rock as found at the depth of 33 meters below the surface at the Culebra, and gave his theory for this formation.

Mr. H. C. Y. Moller, C. E., Ass't City Engineer of Copenhagen, Denmark, exhibited maps of the harbor of Copenhagen, and described the harbor works.

ENGINEERS' CLUB OF PHILADELPHIA—*Record of Regular Meeting, Dec. 20th*, 1884.—Past-President Frederic Graff in the chair.

Mr. Geo. S. Strong read a portion of the first of a series of papers upon the "Future of Locomotive Building. It contained a review of the present and past fast train service in Europe and America, with a discussion as to the possibilities of the future, under the following headings: Fast Express Trains in England; Fast Express Trains on the Continent; Fast Express Trains in America. In all of these the journey speed and running average is given. Are Still

Higher Speeds Wanted? Recent Multiplication of Freight Traffic on American Railways; Train Resistance; Resistance of Grades; Resistance of Curves; Atmospheric Resistance; Have we Reached the Maximum Speed in our Locomotives? The Boiler Power Difficulty; Possible Ways out of the Boiler Difficulty; Economy of Fuel; English *vs.* American Locomotives; Comparative Cost of Slow and Fast Traveling. This and the following papers are intended to be a complete analysis of the problem of rapid train service, both passenger and freight, and of the locomotives now employed in such service; and a consideration of the form and characteristics of the engines which must meet prospective demands. Methods of construction, shop practice, and the necessity for more uniformity in standards, are among the important topics.

Gen. Russell Thayer read a paper upon the "Navigation of the Air, with a Description of the Aerial Ship and the Practical operation of its Motor."

Mr. Lloyd Bankson presented, for Mr. H. W. Spangler, an illustrated paper upon "Measuring Chimney Draft." The ordinary method of measuring is by means of a U tube, partly filled with water. The difference in level in the legs of the U is a measure of the amount of chimney draft. When this is small it is desirable to magnify the reading, and several devices were described for the purpose. One, devised by Mr. Barrus, consisted of two vessels connected by a U tube, the vessels being filled with liquids of about the same specific gravity, but of different colors. The line between the liquids which could be seen in the U tube moved with the amount of draft much more than it would have done in a simple U.

Another device consisted of two vessels of different sizes, each covered with a diaphragm of rubber. These diaphragms are connected together. The inner side of one vessel is connected to the chimney, while the inner part of the other connects with a glass tube, and is filled with water. The water rises and falls in the tube with pressure in the chimney.

The Secretary presented for Mr. P. A. Taylor, an account of the enlargement of the East Mahanoy Tunnel, East Mahanoy Railroad, Schuylkill County, Pa. This tunnel is 3,411 feet long, and was completed during the year 1862.

In the spring of 1876 it was decided by the Philadelphia & Reading Railroad Company to enlarge it, on account of its being too low to permit the passage of engines having the standard height of smoke stack adopted by the company.

To do the work it was first thought that a sufficient amount of the roof could be taken off, but on account of slips and falling rocks, caused by the fact that when the tunnel was driven, several of the coal measures were cut through; it was particularly dangerous, and necessitated timbering in some places; the risks also of detaining trains by having the necessary false works in the tunnel to reach the roof were great, and the coal trade being particularly brisk at that time, the idea was abandoned, and it was decided to take out the bottom, a portion of one side, and a part of the bench that had been left in originally by the East Mahanoy Railroad Company.

On May 29th, 1876, the work was started, and finished September 9th of the same year, costing about $41,000,

The length taken out was 3,411 feet, average depth 2 feet, and width 12 feet, all of which was through conglomerate rock, known only in the anthracite region. In addition to taking out the bottom, various parts of the roof had to be taken down, as well as on the sides of the tunnel, as noted above.

A force of about 225 men was employed in the work, one-half working during the day drilling holes for the blasts and getting everything ready for the explosion of the shots, which generally took place about ten o'clock at night, after the fast Centennial Express passed through. The night force was employed in blasting. No. 2 dynamite was used, and 100 shots put off at one time, by electricity. The debris was then cleared away, and the track blocked up to allow trains to pass through. From ten o'clock until two o'clock during the night was the only time that trains entirely ceased to run through the tunnel.

They labored under great disadvantagefor the want of proper ventilation. The shafts which had been sunk during the construction of the tunnel had been filled up for some years, and the smoke caused by the numerous trains passing through, as well as that produced by the blasts, had to seek an outlet at the east and west ends of the tunnel.

During the whole progress of the work but one train was delayed, and that only five minutes, and the only accident that occurred was the killing of one laborer, caused by his falling under the small engine which was used for hauling away the small trucks loaded with debris from the tunnel.

In the grades of the original road-bed of the tunnel there was a slight adverse grade from the west end to a point about midway, causing the water percolating through the seams of the coal measures, to drain partly into the Susquehanna and partly into the Delaware. Now there is a continuous grade with the trade, relieving a heavy pull of the loaded coal trains after entering the tunnel.

Mr. John C. Trautwine, Jr., presented an illustrated description of a design for a 100-foot turntable, by Mr. C. O. H. Fritzsche, of New York, for the N. Y., W. S. & B. R. R. Co., for use in their car shop It was to carry a six-wheeled shifting engine, 30 feet long, weighing 90,000 lbs., and two cars, each 36 feet long, and weighing 24,000 lbs. each; total extraneous load, 138,000 lbs.

The table is turned by a steam engine, which, with its boiler, is carried upon an iron platform about $7\frac{1}{2} \times 13$ feet, attached to one side of the turntable near the middle of its length, and thus revolving with it. The power of the engine is communicated by means of bevel gearing and a long shaft running along the center-line of the turntable to a wheel in each end carriage.

PROCEEDINGS OF THE ENGINEERS' CLUB OF ST. LOUIS—ST. LOUIS, Jan. 7, 1885.—The

Club was called to order at 8 o'clock by President Moore, thirty-five members and six visitors being present.

The minutes of the last meeting were read and approved. The report of the executive committee was read and approved.

The President appointed the following committee on Smoke Prevention: Prof. William B. Potter, chairman; Messrs. W. H. Allderdice, Theodore Allen, H. Constable, F. H. Pond and C. E. Jones.

Mr. J. B. Johnson stated that the St. Paul Engineers' Club had been admitted to the Association of Engineering Societies, and that the Engineers' Society of Western Pennsylvania, of Pittsburg, were considering the question of joining the Association.

On motion the Secretary was instructed to communicate with the members of the club and ascertain the number desiring membership in the Mercantile Library for the ensuing year.

Mr. John A. Sobolewski read a paper on "Economy in Gas Engines." In the general discussion which followed, he said that the economy consisted in the absence of skilled labor, the cleanliness of the machines, the ease with which they are started, and the absence of risk from fire; also, that the gas-bills were ninety-nine per cent of the cost of operation.

Mr. C. T. Aubin read a paper on "Protection against Fire, and Means of Extinguishing the Same."

On motion, the privilege of the floor was extended to Mr. H. Clay Sexton, Chief of Fire Department. He thought many of our large buildings were built for nothing but to burn down, that the extent of some of our fires was not the fault of the firemen, but the fault of the men who construct the buildings, and the carelessness of those who occupy them.

General discussions followed.

Moved that a committee of five be appointed to investigate the matter of indicating the location of fire-alarm boxes by colored glass in the street lamps, or otherwise, and report at the next meeting.

It was thought that the question was not in the province of the Club, and the motion was lost.

ENGINEERING NOTES.

Our Birmingham correspondent says, a very creditable piece of engineering work has just been accomplished at the Highfield Engineering Works, Bilston, by Messrs. Thomas Perry and Son. It is the casting and polishing to a high degree of perfection a pair of chilled iron rolls, each weighing about 9 tons, for use in a lead works in France. The contract is a repeat one, and was placed in England, since neither in France nor in Belgium could chilled rolls sufficiently hard be obtained, whereas Messrs. Perry claim that the rolls now supplied are harder than steel rolls. They will work one above the other, and are each 24½ in. diameter, by 10 ft. long on the working part, but there is something like an additional 2 ft. on the bottom roll for the fixing on of the wheels. The rolls present almost a mirror surface, and the obtaining of such a face on long and narrow rolls of this description has necessitated much care in the lathe.

IRON AND STEEL NOTES.

Cast Iron Cutlery.—This title may appear anomalous, but cast iron cutlery of certain forms is far more common than its purchasers generally imagine. And it is not necessarily of a poor quality, although made of nothing but cast iron. In the writer's family is a pair of scissors of cast iron that has been used for three years, and has been several times sharpened. The writer has shaved with a cast iron razor, which did excellent work for months. There are in Connecticut two quite extensive establishments which reckon cast iron cutlery as among the important products of their work. This allusion to cast iron shears and scissors does not refer to the combined cast iron and steel articles which are usually considered superior to the forged ones. These have a steel inner plate cemented on each blade by the fused iron when it is poured into the mould; but the cast iron shears and scissors are wholly and entirely of cast iron, and they are finished for the market precisely as they come from the moulds. The quality of the iron used is the same or similar to that used in casting for malleable iron, and for cutlery it is cast in chills. When broken, the crystallization is very similar to that of hardened cast steel, and, except for lack of elasticity, it serves the same general purpose. But although this cast iron is not adapted to tools which work by blows, it is sometimes made into ice picks and axes, hatchets and steak choppers. The manufacturers of cast iron shears and scissors make no secret of the material, and sell their goods for just what they are. Of course they are sold cheaper than forged work of steel can be sold. Retailers, also, know that this cheap cutlery is not steel, and usually—unless dishonest—they will truthfully answer questions on the subject. But, really, a pair of cast iron shears or scissors for ordinary household work is just as good as one of forged cast steel. There is only one difficulty in the way of superseding cast steel forgings by cast iron castings in these implements, which is that the chill that makes the iron hard does not always extend to a depth that will allow of repeated grindings and resharpenings, the material crumbling before it can be brought to an edge. But when first ground and edged, the shears are as keen as those of tempered cast steel, and the blades retain their edges longer.

Remarks on some New Observations on the Working of Steel—By D. Chernoff.—The author, whose name is already well known in connection with the working of steel, read a paper before the Imperial Technical Society of St. Petersburgh on the phenomenon observed by Mr. Beck-Gerhard (*ante*). He stated that seven or eight years ago he had noticed, in cold-sheared samples of steel subjected to a destructive tensile strain, that when the limits of elasticity were reached, the scale on the specimens began to separate in a peculiar manner, and the surfaces of the samples were

marked with curved lines of more or less regularity. He made arrangements to institute an exhaustive inquiry into the meaning of these lines, but unfortunately circumstances obliged him to abandon his intention until the commencement of the present year, when Mr. Beck-Gerhard invited him to examine his specimens, and awakened once more his desire to investigate the subject. The appearance of the rays on the polished surfaces of the steel reminded Mr. Chernoff of the experiments made by Mr. Leger (Sur la constitution des corps trempes. Mémoires de la Société des Ingénieurs Civils, 1877, p. 645), in which the lines of strains produced in glass subjected to various pressures were made visible, through the circumstance of the light passing through the specimens becoming polarized in the regions strained, and therefore capable of being made manifest by being examined through a Nicol prism. Similar observations were recorded in the year 1877 (Société des Sciences Industrielles de Lyon. Séance du 25 Juillet, 1877), and it occurred to Mr. Chernoff that, as in glass bearers the lines of strains assumed various curved forms, so, in metal, similar actions took place, and became, in part, manifested on the surface so soon as the limits of elasticity were passed. In glass the elastic limit coincides with that of ultimate strength, so that it is impossible to fix the waves of strain, but it is worthy of remark that the forms assumed by the fragments of conchoidal fractures resemble closely the lines of strain revealed in glass by the Nicol prism. In metals, on the other hand, the permanent set will begin first where the strains are greatest, and hence the deformation of surface will follow the lines of maximum strain.

Why the regions of maximum strain should arrange themselves in the form of curved rays in metals is as difficult of explanation as the corresponding phenomena in glass; but Mr. Leger suggests that the propagation of strains through elastic substances may be of an undulatory nature comparable to the propagation of sound.

Mr. Rgeshotarsky, one of the officers employed at the Abouchoff Steel Works, undertook to repeat and extend Mr. Beck-Gerhard's experiments, and from his observations it was found that the lines of strain were manifested not only in punching, but in shearing, and in flattening under the steam-hammer. From these experiments the analogy between the visible lines of strain in steel and in glass and sound waves was rendered very striking, because the lines of strain from shearing and punching in the same specimen, and from the two points of compression under the hammer seemed to pass each other without mutual hindrance, except in so far that at the points of intersection the phenomenon of interference was clearly observable. In order to confirm the supposition that shearing produced the same effects as punching, Mr. Rgeshotarsky polished the surface of a ½-inch plate, which had been sheared round its edges, and subjected it to tension beyond its elastic limits. The curved rays emanating from the two sheared edges appeared very distinctly intersecting each other, and were sufficiently prominent to affect the sense of touch. It was noticed by Mr. Beck-Gerhard that the rays are of two kinds. One set, produced by tension, are depressed below the surface, the other due to compression, are raised. What kind of rays should be expected from a specimen which had been sheared, then polished and finally stretched?

Hodgkinson long since noticed that when iron bars, stretched beyond their elastic limits, were again subjected to tension, that the elastic limit was considerably raised; and the same fact may be deduced from the well-known circumstances that drawn iron wire becomes harder and more rigid as it passes through the dies. In the same way, therefore, in the sunk rays produced by the tension due to a shearing force, the metal has been stretched beyond its elastic limit, and consequently that limit has been raised. After obliteration by polishing, when direct tension is applied, the metal in the rays is last to yield, that between them is extended, and forms hollows, leaving the rays prominent. Such is the observed effect, although at first sight it appears paradoxical. Mr. Chernoff acknowledges his inability to discuss the question of the curvature of the lines of maximum strain, but he draws attention to the similarity between the curved lines of fracture in a broken pane of glass and the rays developed by punching and shearing steel. He remarks that the slower the action of the force that breaks the glass the more extensive is the injury, while, under rapid impact, such as from a bullet, hardly any radiating fractures are formed, and he infers that similar results would follow in the case of metal plates, acted on with different degrees of rapidity.

It would be a very useful undertaking, with reference to the strength of guns, and especially of ordnance of large caliber, to investigate the effects produced on the inner tubes by the pressure due to the successive tiers of hoops In spite of very elaborate formulas for calculating the compression produced on the inner tubes by the successive layers of rings, no information exists as to how the strains are distributed in the metal of the tube, because all observation leads to the conclusion that the strains are not transmitted in the regular way assumed by the formulas, but in a wave-like progression forming bands of irregular tension and consequent plains of weakness. Did not the existence of such plains of weakness explain the anomalous behavior of inner tubes, which, though made of excellent metal, carefully tested at every stage of its manufacture, yet crack in an unaccountable manner after more or less prolonged firing?

This paper, as well as the foregoing, is illustrated by numerous plates, for the most part engraved from photographs taken from the specimens.—*Abstracts of the Inst. of Civil Engineers.*

RAILWAY NOTES.

THE SPEED OF ENGLISH EXPRESS TRAINS.—A Paper on English express trains, was lately read by Lieutenant Willock, R. E., before the Statistical Society. A table of the great increase of express services throughout the United Kingdom, forming a portion of the paper, is of more than usual interest at the present time, with the recent accident at Penistone

still fresh in our minds. This may be our excuse for referring more fully to a subject which has a special bearing on the safety of railway traveling. In comparing the express services of 1871 and 1883, we find that the increase of express trains during that period has been 157, or 62.8 throughout the English and Scotch lines, the numbers being 250 per day in 1871, and 407 in 1883. The average journey speed has increased from $37\frac{3}{8}$ to $41\frac{3}{8}$ miles per hour, the running average from $40\frac{4}{10}$ to $44\frac{1}{8}$ miles, and the total express mileage from 23,672 to 42,693, a daily increase of 19.021 miles, or 80 per cent. The London and North-Western stands at the head of the list as regards express mileage, with 10,405 daily miles, but it is not in the same position as regards running average, all the great companies, indeed, having increased in this respect by more than the average amount, with this one exception. The Great Northern stands first in the running average increase, being 42 miles per hour in 1871 and $46\frac{3}{4}$ in 1883, being an increase of $4\frac{3}{4}$ miles per hour. The total express mileage on this system has risen from 3,520 to 6,780, or 92 per cent. The Great Northern, however, shows the greatest number of express journeys on each mile, though in the matter of long runs it of course cannot compete with the London and North-Western, for it is comparatively a short line, and has no long runs extending like those from Chester to Holyhead or Preston to Carlisle. The Manchester, Sheffield and Lincolnshire shows the largest increase of all the lines in the number of district expresses, having risen from 11 in 1871 to 49 in 1883—an increase of 38. As to its average journey speed also, that has mounted from 36 miles to 43—an increase of seven per hour; and in this matter it is surpassed by only one system —viz., the Glasgow and South-Western, which increased by $7\frac{1}{2}$ miles. The running average of the Manchester and Sheffield has of course increased from $38\frac{1}{2}$ miles to $44\frac{3}{8}$, or 6 per cent., and its total express mileage from 594 to 2,318, or the enormous number of 1,724, or 290 per cent. The Midland company ranks third in the number of its expresses, of which there are 66, but second as regards express mileage, being 3,175, in 1871 and 8,860 in 1881—an increase of 6,685 miles, or 147 per cent. Its average journey speed is now $41\frac{3}{8}$ miles—an increase of $4\frac{1}{10}$ per hour since 1871; and its running average is 45 miles—an increase of $4\frac{1}{10}$. The Midland system shows a very large augmentation in the number of its daily long runs, these having been 20 in 1871, with a mileage of 1,135, while now there are 84, with a mileage of 4,377. With respect to the total express mileage, the Great Eastern has made more rapid progress than any other line, having jumped from the bottom in 1871, when it was 161 miles, to the fourth place in 1883, with 3,040 miles—an increase per cent. of 1,788. This is owing largely to the extension of the sytem to Doncaster. The number of district expresses has risen from 3 to 34, its average journey speed from $37\frac{9}{10}$ to 41, and its running average from $38\frac{8}{10}$ to $43\frac{1}{4}$. As representing the West of England, the Great Western, though it still stands fifth in the order of total express mileage, has actually reduced its number of district expresses from 28 to 18, and therefore, of course, its total express mileage, which now stands at 2,600 daily miles. Its average journey speed has risen from 38 to 42 miles, and its running average from $41\frac{1}{8}$ to $46\frac{1}{4}$. For the southern lines the changes are nothing like so great. The Chatham and Dover has increased its district expresses from 6 to 9, the Brighton from 12 to 13, while the South-Eastern has reduced them from 15 to 12, and the South-Western from 7 to 3. In speed, however, the latter company shows best of all the lines south of London, having risen from 40 miles to $44\frac{1}{3}$, the Chatham and Dover following suit from $41\frac{3}{4}$ to $43\frac{1}{8}$, the South-Eastern from $40\frac{1}{2}$ to $41\frac{3}{4}$, and the Brighton from $41\frac{1}{3}$ to only $41\frac{5}{16}$. This very small increase is doubtless due to the crowded state of the line between London and Croydon, which would render a very high speed inadmissible. It ought to be added that, notwithstanding the increase of speed, accidents have become less rare, owing to the greater care employed and the more general adoption of efficient brake-power by the more enlightened railway companies.—*Iron*.

ORDNANCE AND NAVAL.

GUNS FOR THE NAVY.—During the discussion on Sir. E. J. Reed's paper at the United Service Institution, the need of guns for our armaments was repeatedly referred to. We learn from Lord Northbrook and Sir Thomas Brassey that a separate vote of money for this purpose for our new ships amounts to £1,600,000. As we have in our war ships now in commission nothing but old type guns, it is very desirable that the supply of guns of new type should not be limited to new ships only. Most of our readers are aware that new guns differ from our old guns mainly in three respects: (1) They are breech-loaders; (2) they are constructed wholly of steel; (3) they are so proportioned as to discharge a projectile with a deal more energy or stored-up work in it than the old guns, which is effected by their length and dimensions of powder chamber admitting of a much larger charge of slow burning powder being burnt, the pressure being better kept up through the bore. The shot thus discharged has greater power both for the perforation and for the smashing up of armor, but the latter not by any means in the same proportion as the former; for the diameter of the projectile being smaller than formerly, as compared with its weight, it experiences diminished resistance in its passage through soft armor, whereas against really hard armor where a hole is only made by breaking up the plates, the effect is simply proportional to the stored-up work, a fact that must be borne in mind when considering the powers of guns registered, as they generally are, solely with a view to their perforation.

With regard to the supply, we fear that for the heaviest pieces for which it is difficult to get steel we may wait some little time. On the other hand, the chief gun in the constitution of our secondary armaments is the 6in gun—Mark IV.—firing a charge of 50 lbs. of powder. Guns of this caliber can be rapidly turned out, though perhaps it would be rash to speculate at what rate exactly. The largest guns re-

quired are of 110 tons' weight, for the Benbow. These are ordered from Elswick. In *The Engineer*, June 27th last, page 488, writing on Colonel Maitland's paper, we gave a figure of this gun in section. At present it is the most powerful gun designed. Other vessels of somewhat the Benbow type will carry the 63-ton gun made in the Royal Gun Factories. This has greater calculated muzzle energy than any gun made out of England at present, except Krupp's 119-ton gun, viz., 36,415 foot-tons, with a perforation of 28.6in, of iron; the Krupp gun having 46,061 foot-tons energy and 29.2in. perforation. The Elswick 110-ton gun has 50,924 foot-tons calculated energy and 30.5 in. perforation. The Gun Factory gun and Krupp's piece are also shown in section in *The Engineer* of June 27th last. These guns are, of course, enormously powerful. The French 71-ton gun has 31,272 foot-tons energy and 24.5in. perforation. These guns are likely to appear only as single champions, firing experimentally, for some little time yet. The nation that first has any considerable supply of them will be the nation that has the best steel makers, for on this all depends. Practically, however. the supply of 6in. guns is equally important. Our turret-ships specially come short in secondary armaments of guns, and some foreign designs almost appear to have been framed so as to take advantage of our paucity of pieces by exposing their men *en barbette* and the like, trusting to the fact that no one would point an 80-ton gun at a single man, or two or three together in a gun detachment. It is necessary to arrange in what way these 6in. guns can be introduced into our mastless turret type, and in the meantime the gun factories, and private firms too, ought to be kept pretty busy. To return to the heavy guns. Our readers can best judge of their practical power, perhaps, by the fact that while 19in. is the thickness of plate adopted generally for very heavy armor, the perforations of these guns which we have given above so greatly exceeds it, that there is now no ship afloat that can resist such pieces. L'Amiral Duperré, quoted by Sir E. J. Reed, has less than 22in. of steel maximum armor. A fair blow from any of the above heavy guns—that is, the Krupp, Elswick, Gun Factory, or French gun—would smash up such armor easily. L'Amiral Baudin and Inflexible would come little or nothing better off, and no vessels carry thicker armor. We mention this because it is generally felt that guns have somehow lagged. In numbers there may be some truth in this, but it is due to the rapid development of power which made our designers pause before pushing on large supplies. Now we trust that the matter has taken a sufficiently settled form to enable production to be pushed on.

We may add that our authorities having at length been made acquainted with the secrets of cocoa powder, samples have been delivered made at Waltham Abbey, which have given excellent results. We trust that steps may be taken to enable the work of making guns to be at last pushed forward with due regard to the present position of the Navy.—*Engineer.*

BOOK NOTICES

PUBLICATIONS RECEIVED.

TRANSACTIONS of the American Institute of Mining Engineers, Vol. XII.

Report No. 2 on a Water Supply for New York and other Cities of the Hudson Valley. By J. T. Fanning, C. E.

Sound Signals. By Arnold B. Johnson.

Annual Report of the Engineer Department of the District of Columbia. Maj. Garrett J. Lydecker, U. S. Engineers.

Danger Lines and River Floods of 1882 (Signal Service Notes No. XV.). By H. A. Hazen.

Manuel de Manipulations Chemiques. Par Fr. De Walque. Lauvain: Preters Ruelins.

Hydraulique Fluviale. Par M. C. Lechalas. Paris: Baudry.

Traite Generale des Vins. Par Emile Viard. Paris: F. Lavy.

Theorie de l'Elasticite des Corps Solide. Par M. de Saint Venant. Paris: Dunod.

THE STABILITY OF SHIPS. By SIR EDWARD J. REED, K. C. B., F. R. S. London: Chas. Griffin & Co. Price $7.50.

The scope of this book is fully explained in the title and name of the author.

It is hardly necessary to say more than that it is a scientific treatise of 366 pages, illustrated by 225 diagrams and five folding tables.

The whole work is divided into nineteen chapters. These present, in succession, the various methods that have been employed of determining the metacenter, and the conditions of stability.

CASSELL'S FAMILY MAGAZINE. The Magazine of Art. New York: Cassell & Co.

The Magazine of Art for February is an elegant number. Illustrations and letter-press are both excellent.

TEXT-BOOK OF DESCRIPTIVE MINERALOGY. By HILARY BAUERMAN, F.G.S. London: Longmans, Green & Co. 1884.

This is the companion volume to the "Systematic Mineralogy," by the same author, published in 1881. As far as space admits Mr. Bauerman endeavors to describe all the more important mineral species. His remarks about the names of minerals and their derivations are well chosen; and both mining students and teachers of mineralogy should note the following paragraph:—"In the case of minerals worked as metallic ores, the ordinary commercial names should always be used where possible. Thus for all purposes copper pyrites, tinstone, and zinc blende are preferable to chalcopyrite, cassiterite, and sphalerite."

The classification adopted by the author "is in the main similar to that of Rammelsberg's 'Mineral-Chemie.'" Each description gives the form, the structure, the composition, and chemical characteristics, and concludes with the occurrence and distribution of the mineral. The crystallographic form is indicated both by Miller's notation and that of Naumann; and the figures of crystals are from the excellent wood blocks used originally for Brook and Miller's "Mineralogy."

As might be expected from the author's wide experience as a traveler, the parts relating to occurrence are generally quite as complete as is compatible with the size of the volume; but strange to say, under the head of copper pyrites, the author omits all mention of the great mines of the provinces of Huelva in Spain, and Alemtejo in Portugal. It is true that they are not forgotten by him when speaking of iron pyrites; but Rio Tinto, which produces more copper than any other mine in the world, surely deserves notice quite as much as Devon Great Consols, Mellanear, or South Caradon. We must here correct an error of the author, who places Buitron in Portugal, whereas it is in Spain; and the great Portuguese mine is at San Domingos, not at Pomaron, which is simply the port of shipment, about eleven miles from the actual workings. . . . . .

We regret that there are occasional errors of spelling in the names of minerals and places. Thus "Freieslebenite" appears several times without the second "e," though it stands correct in the index, and "Meconite" might puzzle the novice who had never heard of Meionite. However these are slight blemishes, and both they and the few other mistakes can easily be corrected in a second edition, which no doubt will be required, as Mr. Bauerman's manual is clear, compact, and handy, and is likely to be a favorite with students of mineralogy.—*Nature.*

MAGNETO-ELECTRIC AND DYNAMO-ELECTRIC MACHINES: THEIR CONSTRUCTION AND PRACTICAL APPLICATION TO ELECTRIC LIGHTING AND THE TRANSMISSION OF POWER. By DR. H. SCHELLEN, Director of the Real Gymnasium at Cologne, etc. Translated from the third German edition by Nathaniel S. Keith and Percy Neymann, Ph. D., with very large additions and notes relating to American machines, by NATHANIEL S. KEITH, Secretary of the American Institute of Electrical Engineers. Vol. I., with 353 illustrations. New York: D. Van Nostrand, 1884.

The extraordinary progress which has been made within the past few years in the industrial application of the dynamo-electric machine, especially in electro-metallurgy, electric illumination and last, but by no means least in importance, the transmission of mechanical energy, has had the inevitable result of stimulating the production of an enormous volume of literature, relating to the subject, of more or less value—generally less. A succession of would-be authors, each anxious to be first in the field, have loaded the shelves of the electrician's library with books consisting mainly of a crude and ill-digested mass of extracts from the reports of exhibitions and the catalogues and advertising circulars of manufacturers, abounding in erroneous descriptions and still more erroneous theories. In these works we find repeated, again and again, the venerable blunders with which constant reiteration has rendered us so familiar, accompanied by equally venerable engravings of machines of which some never had an existence and others have sunk into deserved oblivion.

It is encouraging, however, to notice that a marked change in the character of electrical literature is becoming perceptible. Several works have recently been published of real and permanent value, not only to the theoretical electrician, but to the electrical engineer and the practical workman as well.

Dr. Schellen, the author of the present work, whose lamented decease was chronicled but a few days since, was director of a technical institution at Cologne, Germany, and is best known among electricians as the author of one of the earliest as well as the best treatises on the electric telegraph, which has gone through a great number of editions and still retains its place as one of the leading works on that subject. It would, perhaps, be difficult to name any one person better qualified to prepare a work of this particular kind than was Dr. Schellen. It is true that the character of the book shows him to be a theoretical rather than a practical man, for his lack of thorough familiarity with the conditions of actual work occasionally betrays him into obvious errors. In the present volume, which has been translated from the German by Nathaniel S. Keith and Percy Neymann, the original work has been carefully edited by Mr. Keith and many such errors corrected. The editor has also added a considerable amount of new and valuable matter descriptive of American machines and practice, which greatly increases the value of the work to American readers. The number of dynamo and magneto machines which have been devised by the ingenuity of inventors is so great as to render it hopeless to attempt to describe them all in a single work. In making a selection the author states that the considerations which have guided him have been either novelty in principal, extensive technical application, or a great degree of historical or theoretical interest. Part I. is devoted to a preliminary explanation of the physics of electricity and magnetism. This portion of the work is exceedingly well written, and contains matter of considerable value to the student. We do not remember to have seen any instance in which the reactions of the solenoid and movable core, so much used as a regulating device for arc lamps, is more lucidly explained and illustrated. The engravings in *fac-simile* of magnetic spectrum, showing the lines of magnetic force under different conditions, will well repay careful study and comparison. Part II. treats of methods of electric measurement and of measuring instruments. The portion relating to the dynamometer, and the methods of determining the power imparted to the dynamo is unusually full. The American editor has added descriptions of the Kent and Brackett dynamometers, the latter of which is unquestionably the most convenient and accurate apparatus yet devised for this purpose. The photometer and the manner of its use are also well described. The portion of the chapter relating to electrical measurement proper is, however, hardly what we have a right to expect in a work of this character, no reference being made to some of the most important instruments for measuring large currents, such, for example, as the graded galvanometers of Sir W. Thomson.

Parts III., IV. and V. are devoted to magneto

and dynamo electrical machines. In this work, for the first time, so far as we are aware, the evidence in favor of each of the several claimants to the discovery or invention of the self-exciting dynamo has been brought together in a form convenient for discussion and comparison. It is very well known that the discovery of this principle was announced independently about the same time by Dr. Siemens and Prof. Wheatstone, but it is not so well known that Moses G. Farmer, the well-known American electrician, was also an independent discoverer of the same principle. It appears that Siemens exhibited his machine, illustrating the principle in question in December, 1866, and prepared a paper which came before the meeting of the Berlin Academy of Sciences in the middle of January, 1867. The original paper translated from Poggendorff's *Annalen* is given in full. On February 14, 1867, Professor Wheatstone read a paper before the Royal Society on the same subject. The evidence in support of Professor Farmer's claim has never before, so far as we are aware, been published in full.

As a further contribution to the history of the dynamo, Mr. Keith has added a translation of the article of Dr. Paccinotti, published in 1864 in *Il Nuovo Cimento*, containing a description of his continuous current electro-magnetic machine.

The descriptions of the modern machines have been prepared with care, and are sufficiently well illustrated. We find, for the first time, descriptions of some of the modern American machines, which, although in extensive use, have not heretofore found their way into the books, such as the Thomson-Houston, the Fuller-Gramme, and the Weston constant potential machines.

The final chapter in the book is devoted to a classification of dynamo-electric machines, and a discussion of the theory involved in their construction and operation, which is mainly a compilation of the results of the investigations of Dr. O. Frolich and Marcel Deprez.

We must call attention to one serious fault in the translation or editing of this work, which, with a little care, might easily have been remedied. We refer to an indiscriminate use of the terms electromotive force, tension and intensity, which is eminently well calculated to confuse the ordinary reader. Take, for example, the statement on page 344, that the Weston armature is calculated to produce currents of low *tension*, but of great *intensity*. Here the the word "tension" is obviously used in the place of "potential" or "electromotive force," and "intensity" in place of "quantity." We might point out a number of other instances of the same kind. The weights and dimensions throughout the book are sometimes given in English measure and sometimes in metric measure, which is extremely inconvenient for the student. A better method, which we are glad to see is rapidly coming into use among scientific writers, is to give the weights and dimension in metric measures, followed by the English equivalent in brackets. This is especially proper in electrical work, inasmuch as the accepted electrical units are based on the metric system. We do not find that the value of the standard ohm as ultimately established by the Paris Congress, or the latest determination of the value of the ampere by Lord Rayleigh are given. These, perhaps, have been too recently published to admit of their incorporation in the body of the work, but might, we should think have been advantageously added in an appendix.

The mechanical execution of the work is excellent. The illustrations are abundant, and for the most part well designed, and, although to a certain extent lacking in finish, are, on the whole, very creditable.—*Electrician and Electrical Engineer.*

OPERATIONS OF THE ARMY UNDER BUELL—From June 10 to October 30, 1862, and the Buell Commission. By JAMES B. FRY. New York: D. Van Nostrand.

To those who served in the war of the Rebellion, the various monographs which are now coming out from time to time, on the particular battles or campaigns in which they may have taken part, furnish most interesting reading. This is, of course, especially the case when the monograph comes from one who has had unusual opportunity to know the facts about the campaign under discussion Such monographs generally serve to show to those who were on the field, and participated in the movements and the fighting, how little they really knew about what seemingly went on under their own eyes.

Thus, to most of those who were actors in the campaign and battle of Perryville, General James B. Fry's "Operation of the Army under Buell" will give much new light, whether or no it shall change their previously formed opinion upon the merits or demerits of the chief commander. Many side lights are thrown upon the scene, and it is shown that not alone a commander's courage or capacity or genius, but many other things, enter into the determination of his success or failure in the field. His tact or want of tact in obtaining the good-will or incurring the enmity of some subordinate officer who chances to have the ear and the favor of some one in official authority, may have almost as much influence upon his career as his own capacity or incapacity.

In July of 1862, General Buell was in command of our forces in Northern Alabama and Central Tennessee. His orders were to repair his railroad communications, and then, if possible, capture Chattanooga. The Rebel authorities became alarmed, and collected a large force under Generals Bragg and Kirby Smith to oppose him. General Fry seems to prove conclusively that the Rebel armies greatly outnumbered General Buell's forces. In August they poured through the mountain passes of Eastern Tennessee, threatening Buell's left and rear, and endangering not only all Eastern Kentucky, but also the cities of Cincinnati and Louisville. Buell marched northward, concentrating his scattered troops, manœuvering for position, and offering battle at several points in Kentucky. Bragg was wary, and declined to fight, notwithstanding delay weakened him and strengthened his enemy. Buell

finally entered Louisville, was joined by many newly recruited and raw regiments, reorganized his army, and, although still outnumbered, early in October advanced rapidly upon Bragg. The latter fell back; and on the 8th of October was fought the battle of Perryville. Neither army was present on the field in full force, and though the battle was bloody and obstinate, it was seemingly indecisive. Buell expected the final conflict to begin on the following day, and prepared for it; but to his surprise, Bragg retreated during the night. Buell followed in pursuit, but found it impossible again to force his adversary to battle. As another Rebel force was then threatening Nashville, Buell left the pursuit at Crab Orchard, and on the 16th of October turned his army toward Nashville.

It is notorious that at this time there was great discontent in Buell's army. He had had to grapple, as a soldier, not only with military problems, but with all the troublesome questions growing out of the relations of his troops to the negro slaves and to their Rebel masters. Like most soldiers, he was a strict constructionist where laws and orders were concerned. He returned slaves which the laws did not yet allow him to free, and he punished with great severity all officers and men who were guilty of depredations upon Rebel property. This was hotly resented by his thinking bayonets, who had little respect for a discipline which conflicted with their most cherished political ideas. The discontent and almost insubordination which grew from these causes not only pervaded the army but was quickly communicated to influential persons in the North. General Fry seems to show pretty conclusively that there was little reason, up to this time, to criticize General Buell's military conduct of the campaign; and that the Government was at that time of the same opinion, is shown by the fact that on the 18th of October General Halleck, then the military adviser of the President at Washington, telegraphed to General Buell: "The rapid march of your army from Louisville and your victory at Perryville have given great satisfaction to the Government." Yet on the 24th orders were issued at Washington directing General Rosecrans to relieve General Buell of his command.

One may well ask, on what was this sudden change of opinion by the Government founded? Was it not caused by a single dispatch from one who is often called a "great war Governor"? And on what was that dispatch founded? Seemingly on the verbal report of "an officer just from Louisville." Who was that officer? what opportunity had he for full information? what was his capacity or fairness? what private grievance or resentment had he? These are things which history will never know; and yet his conversation with Governor Morton probably greatly changed, for better or for worse, the conduct of the war in the West. Here is the dispatch of Governor Morton, sent to President Lincoln on the night of the 21st—only two days before Buell's removal from command:

"An officer just from Louisville announces that Bragg has escaped with his army into East Tennessee, and that Buell is countermarching to Lebanon. * * * The butchery of our troops at Perryville was terrible. * * * Nothing but success, speedy and decided, will save our cause from utter destruction. In the Northwest, distrust and despair are seizing on the hearts of the people. O. P. MORTON, Governor of Indiana."

The order for Buell's removal was dated only two days after this dispatch, but it was not made known to either the public or to General Buell until some days later. That it was quickly communicated to Governor Morton, however, is shown by the following dispatch, which was received by President Lincoln on the morning of the 25th:

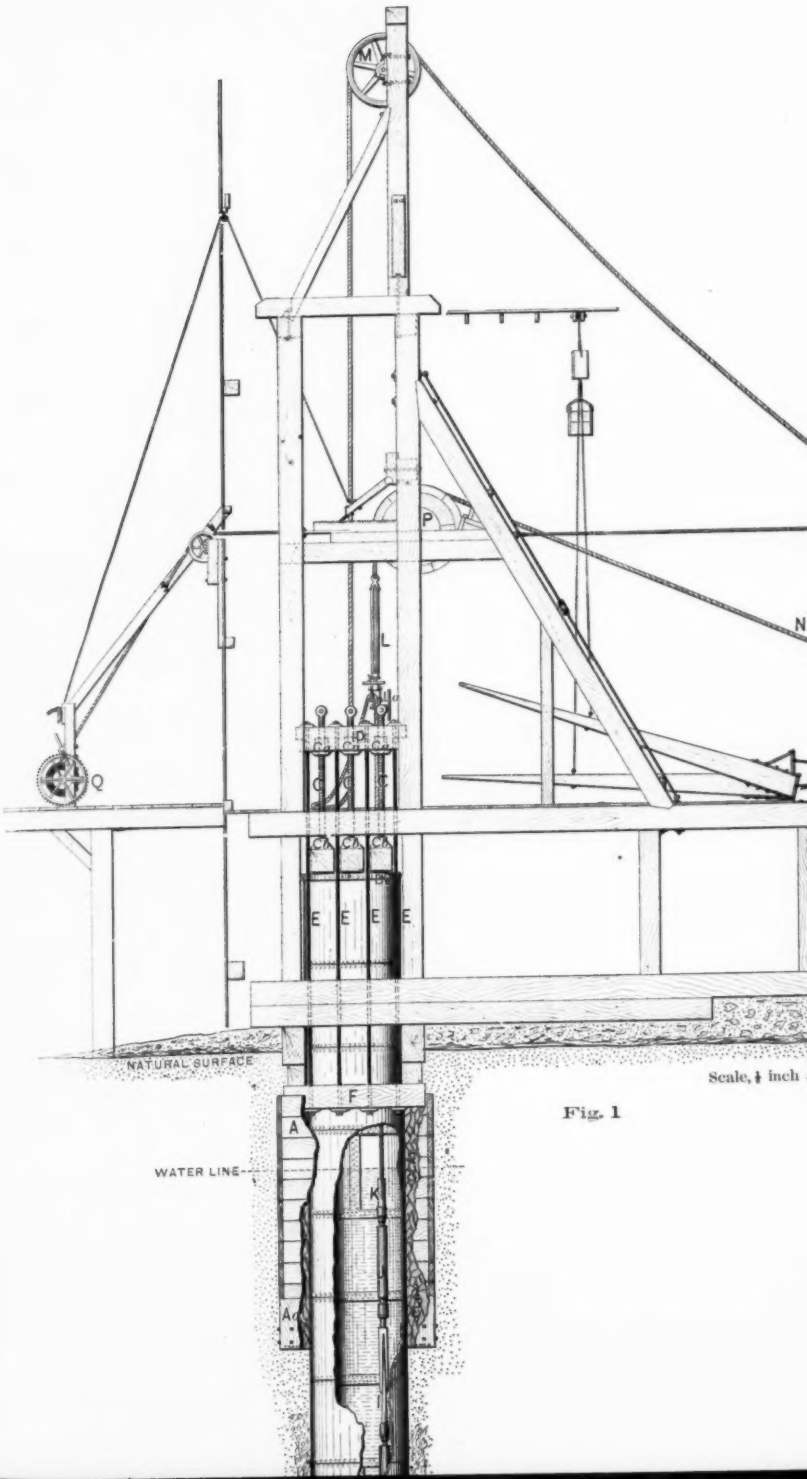
"We were to start to-night to Washington to confer with you about Kentucky affairs. The removal of Buell and appointment of Rosecrans came not a moment too soon. * * * The history of the battle of Perryville and the campaign in Kentucky has never been told. The action you have taken renders our visit unnecessary."

This was signed "Richard Yates, Governor of Illinois," and "O. P. Morton, Governor of Indiana." Verily, as General Fry says, "this has a dictatorial ring." Evidently the "great war governors," who were supposed by the public to be busy putting men into the field, had something to do with taking men out of the field.

The fact is, great as were Buell's abilities and accomplishments as a soldier, he had never learned *tact*. Busied with the great end he had in view—the destruction of the Rebel army in his front—he was not careful about what opinions certain of his majors and colonels and brigadiers, who had the ears of the "war governors," might be forming of him. He did not see that his unmeasured words to an offender against discipline, and his protection of some Rebels' property, might be as potent factors in determining his own career as his success or failure in the field. He believed in discipline, and he enforced it upon all alike. He believed that the discipline of his own troops required that outrages upon Rebel property should be punished with severity, and that, as a military commander in the field, he had nothing to do with the freeing of the slaves of Rebel owners. His government had not yet undertaken this mission, or given him orders which would justify such action. He obeyed orders himself, and insisted on the obedience of others. He did not doubt that his motives and his actions would be understood. He was mistaken. But though he suffered, the army he trained never entirely lost some of the good qualities he gave it; and at least something of the service afterward rendered, something of the glory afterward gained, by the Army of the Cumberland, should be credited by his countrymen to General Don Carlos Buell. — ALEXANDER C. MCCLURG *in the Dial*.

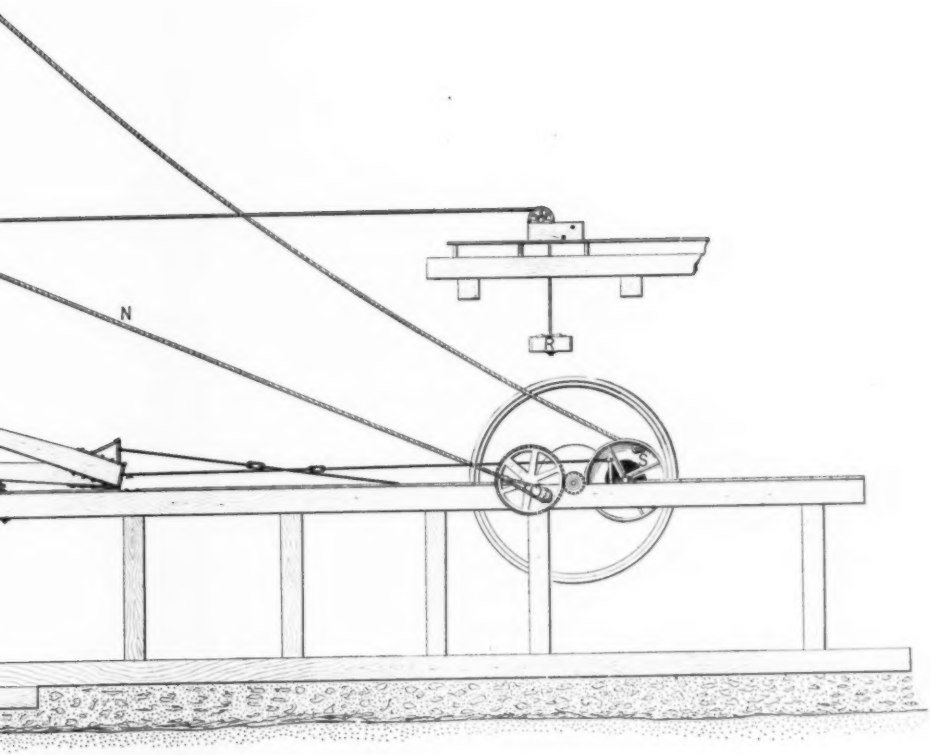
MISCELLANEOUS.

THE "Two Manners of Motion of Water," shown by experiments, will be the subject of a lecture before the Royal Institution, March 28.

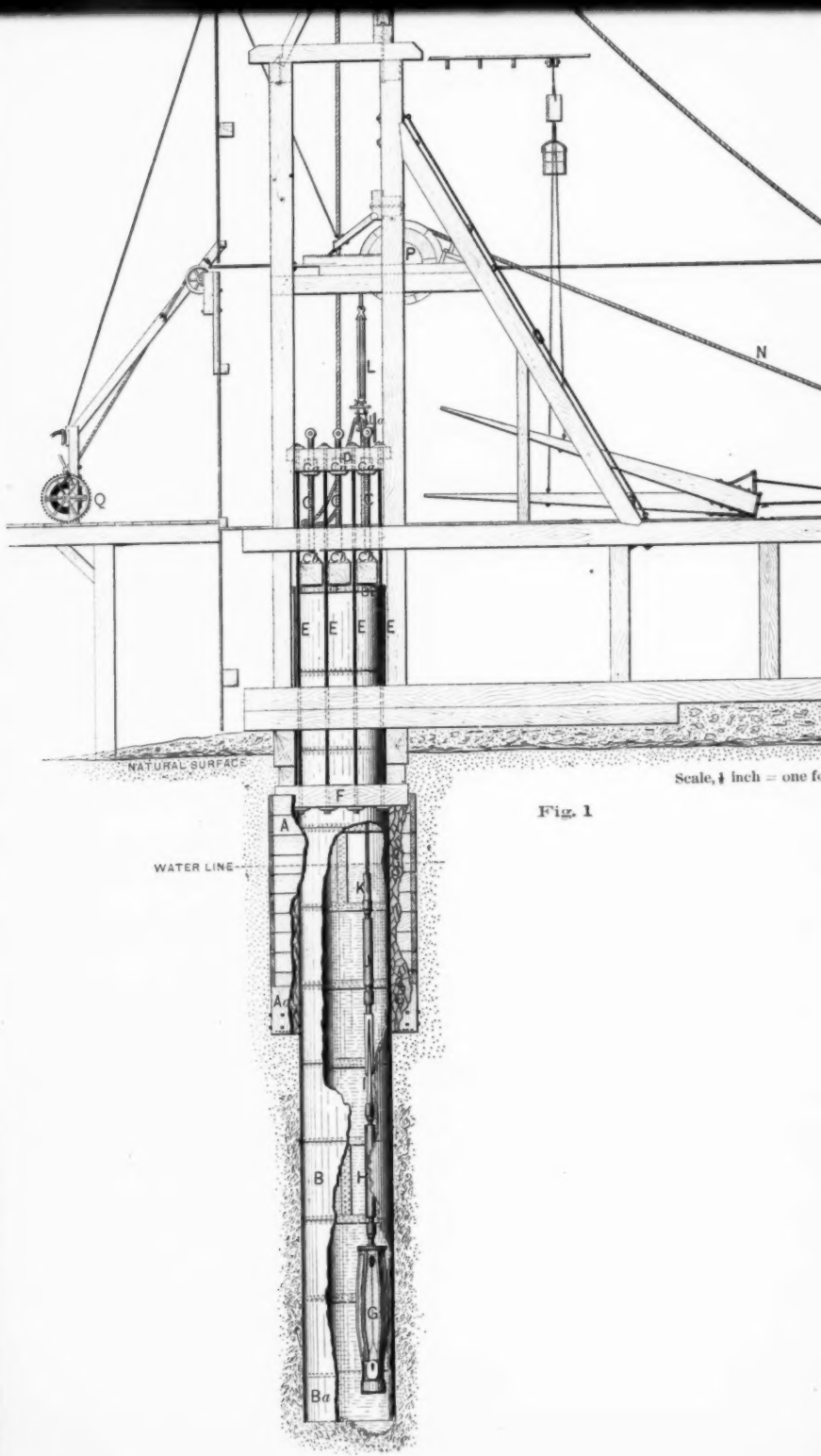


Scale, ½ inch

Fig. 1

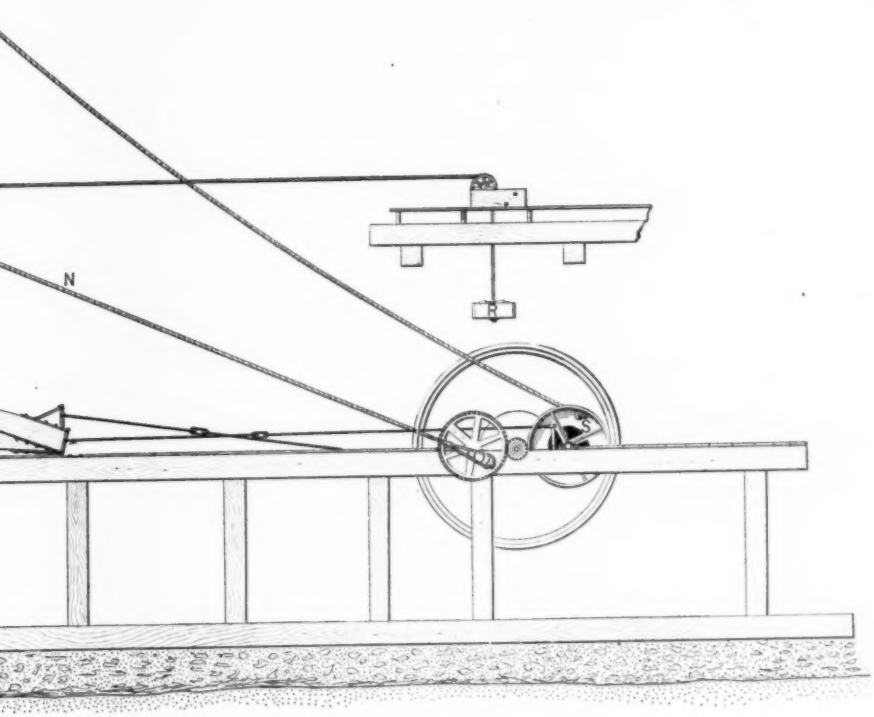


Scale, ½ inch = one foot



Scale, ½ inch = one fo

Fig. 1



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